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CORTICAL LOCALIZATION OF SYMBOLIC PROCESSES IN THE RAT: III. IMPAIRMENT OF ANTICIPATORY FUNCTIONS IN PREFRONTAL LOBECTOMY IN RATS

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The concept of the symbolic process has been used since the early days of British associationism, but it is Hunter (**5**) who has attempted to define its meaning in behavioristic terms and to devise tests for the presence and operation of the process. Among those who have used or extended these tests and have employed the concept there is still some variation in the precise meaning of the concept, but in general it refers to any psychological function which is a substitute for or representative of stimuli or responses not present at the time of the process and which is capable of arousing selective behavior. Theoretically, such a process could consist either of implicit S-R functions, after the fashion of behavioristic conceptions, or of central brain processes, as in the imagery or thought of older association theory. Although we profess a bias for the latter view, for the present purpose it does not matter which of these views is adopted.

Psychoneural investigations of the last few years have pointed to the conclusion that at least certain of the symbolic processes are specifically mediated in primates by the prefrontal 'association' areas. Jacobsen (**6**) found recent memory, 'set' and the ability to order a series of responses in their proper sequence disturbed by removal of these prefrontal areas in monkeys. All of these functions may be conceived as involving symbolic processes (**9**).

More recently Malmo (**8**) has reported that recent memory is not necessarily disturbed by such operations and that the fundamental impairment is of the ability to maintain a set. So it seems that the motor or expressive aspects of symbolic function, but not the sensory or receptive aspects of them, are primarily dependent upon the pre-

frontal areas. Similar findings are obtained in human individuals subjected to section of the radiations to the prefrontal cortex (1).

With these findings in the background, Stellar, Morgan and Yarosh (13) reopened the question of the localization of memory functions in the rat's cortex, for it seemed possible that a more analytic approach, in terms of different types of memory function, might reverse to some extent the conclusions based upon maze studies. Selecting a type of maze in which the importance of external cues was largely, if not entirely eliminated, and the importance, therefore, of symbolic processes was high, these authors carried through a series of cases with lesions in different parts of the cortex and obtained rather good evidence that performance in this maze was dependent primarily upon the prefrontal areas of the rat and little, if any, upon other areas. Next, Morgan and Wood (11) carried out a similar experiment, using the method of delayed alternation, and found again primary dependence of this performance upon the prefrontal areas. This result further strengthened the conclusion that symbolic functions, at least of the sort tested, have a functional localization in the prefrontal areas.

The present study carries this type of analysis another step further by investigating the relation of the prefrontal areas of the rat to another phenomenon of maze performance thought to be evidence of symbolic function. This is the anticipatory retardation in the rate of running of rats prior to reaching the goal in a maze.

A few years ago, it will be recalled, Hull (3) put forth the 'goal gradient hypothesis' that stimuli in a maze should acquire excitatory tendencies in learning in proportion to their nearness to the goal. To provide one test of this hypothesis, Hull (4) studied the rate of running in a maze throughout different stages of learning and obtained a speed-of-locomotion gradient (trial-gradient) in approach to food that was in accord with the hypothesis. Later Morgan and Fields (10) supported Hull's findings with the report of a gradient of locomotion throughout a series of trials (series-gradient), adjusted apparently to the larger goal of the day's ration of food.

The goal gradient hypothesis and the phenomena of trial- and series-gradients, it would appear to us, do not concern any symbolic process but refer only to the dependence of maze performance upon external cues. In connection with the development of the goal gradient hypothesis, however, Hull postulated an 'anticipatory goal reaction' (2) which consisted of that fraction of the goal response which is compatible with maze running and serves as the purpose, image, or expectancy of the final reward. The concept of the anticipatory goal reaction has the properties of a symbolic process in that it represents to the animal the reward-situation that will be achieved

at the end of the maze. The anticipatory goal reaction is responsible, Hull suggested (**4**), for the terminal retardation seen in the speed-of-locomotion trial-gradient and, after prolonged training, in the series-gradient (**10**).

In the difference between the goal gradient phenomenon and the anticipatory goal reaction we have another opportunity for studying the possible localization of symbolic processes in the rat's prefrontal areas. The hypothesis for experimentation is this: Both a speed-of-locomotion gradient and an anticipatory retardation just prior to the goal should appear in the maze behavior of normal animals, but only a speed-of-locomotion gradient without any terminal retardation should be obtained in prefrontal lobectomized animals, if symbolic processes are dependent upon the prefrontal areas. The present experiments were carried out to test this hypothesis; and it may be said, in anticipation of the results, that it was confirmed.

Apparatus and Procedure

To study the speed-of-locomotion gradient it was desirable that the maze used have two important characteristics: the path should be relatively long so that measures of time over its parts would be accurate; and the maze should be relatively simple and homogeneous in design so that special features of one part of the maze could not weight the time spent in that part. The latter criterion is well met by Lashley's Maze III (**7**), which consists of enclosed alleys with culs arranged so that the correct path through the maze is a pettern of single alternation, 4 right and 4 left turns. The first criterion was met by simply doubling the length of the maze. Two such mazes were placed side by side so that the true path was a single alternation pattern of 8 right and 8 left turns and was 18.4 feet in length.

Time spent on each of three segments of the maze seemed to be adequate for determining the speed-of-locomotion throughout the maze. Since, furthermore, the structure of the maze was such that it was most convenient to divide it into quarters, time was taken on the first half, the third quarter, and the fourth quarter of the maze. For each of these segments there was an electric clock operated by the observer pushing sensitive switches. As the animal crossed from one segment into another, the observer simply depressed one switch and released the one that he had been holding. The error in this method is of the order of .2 sec., but since the average time on one segment was seldom less than 3 sec., this error was considered negligible.

The subjects were 16 brown rats drawn from a colony derived from the crossing of Wistar albino and trapped wild gray ancestors. These 16 animals were divided into two groups of 8, matched so far as possible in terms of age, weight, and sex. The two groups were placed on a 24-hour deprivation schedule and given enough food per animal to bring them down slowly to about 85 percent of their initial weight. The amount of food necessary to keep them at about this level was determined for each rat and fed to the animals regularly at the same time each day.

Then one group was subjected to prefrontal lobectomy. The anesthetic used was a small amount of ether and then chloral hydrate in proportion to body weight. Two trephine holes were made as nearly over the prefrontal regions as possible and the meninges pierced with a needle. Then a small bent probe was used to loosen up the brain tissue, and the tissue was removed by suction with a curved glass pipette attached to an aspirator. The minimum interval between operation and the first postoperative training was three days, but in many cases it was considerably longer.

For several days before the operation as well as following it the animals had been on a feeding schedule preparatory to the behavioral tests. The normal rats, of course, followed the same routine except for operation.

In order to avoid unnecessarily long sessions with rats during their first trials in the apparatus, preliminary training was given on a five-foot straightaway. This consisted of 5 rewarded

trials on each of two days. Then, on a third day the rats were given 5 trials in the first half of the maze which was later to be the standard instrument. Some learning occurred in these trials, but that is required for the appearance of the gradient of locomotion anyway, and we were not particularly interested in learning performance. On the fourth day, finally, training began in

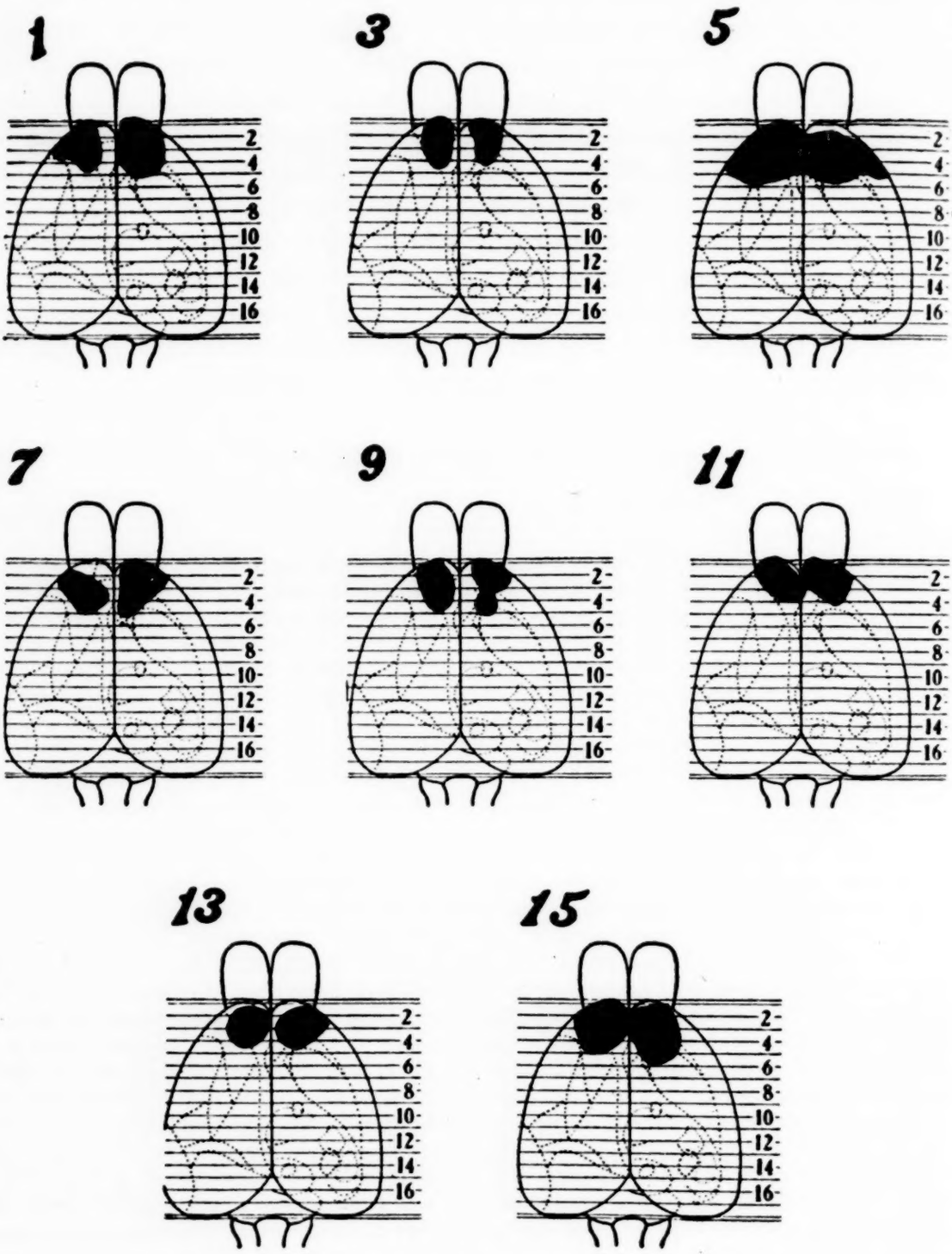

FIG. 1. The lesions of each of the operated rats.

the maze proper. It continued for 5 trials each day for 13 consecutive days, and the performance throughout these days constitutes the data to be considered here.

Each operated animal was killed after it had completed its last day of running; its brain was removed, placed in alcohol and allowed to dehydrate for a few days. Then by careful

measurement with calipers of the amount of tissue removed, the lesions were drawn on standard diagrams. The drawings made in this way are not as accurate as those made after sectioning and staining of the brains, but they are adequate for the present purposes. As one can see from Fig. 1, the lesions are all placed well in the prefrontal areas as intended, and there is consequently no reason to distinguish between the animals in terms of the position or the size of lesions, and no analysis of results according to type of lesion will be presented here.

Results

As stated earlier, it was expected that, following the above procedure, we should find two gradients in the speed-of-locomotion of rats progressing through the maze: an accelerating gradient from start to goal, which we may call simply the 'goal gradient,' and a decelerating of speed near the goal in anticipation of reward, which we may call the 'anticipatory gradient.' From previous work it could be expected that the 'goal gradient' would appear shortly after the beginning of training and then in the later stages of running would gradually subside. The anticipatory gradient would also be

TABLE I

The Mean Number of Seconds Required for the Normal and Operated Groups Respectively on Each Segment of the Maze, Each Trial of the Five Trials Given Daily, and Each of the Three Groups of Days: the First Five Days, the Next Four Days, and the Final Four Days

Segment A of the maze measured 9.2 feet (true path); Segment B, 4.6 feet; and Segment C, 4.6 feet.

Trial	Normal			Operated		
	A	B	C	A	B	C
			Days 1–5			
1	64.6	19.1	13.9	116.1	19.7	13.7
2	21.8	8.1	6.4	42.0	13.9	9.0
3	18.2	9.5	6.0	41.6	10.3	6.7
4	14.5	5.4	4.9	28.7	11.6	7.5
5	23.5	7.1	6.4	26.5	8.6	5.1
			Days 6–9			
1	18.8	6.7	6.1	44.4	10.7	8.5
2	10.0	3.5	3.6	25.7	8.0	4.1
3	8.3	3.1	4.0	18.0	5.1	3.2
4	7.1	3.2	4.2	18.3	5.2	3.7
5	6.0	3.1	4.2	15.4	4.3	3.0
			Days 10–13			
1	14.7	5.8	5.4	37.3	8.5	7.7
2	10.8	3.6	3.6	21.2	7.7	3.3
3	7.3	3.2	4.1	18.2	6.0	3.0
4	6.3	2.7	4.2	16.5	4.2	3.5
5	4.5	2.5	3.5	14.3	4.3	3.4

expected to develop after the beginning of training, but at a considerably later stage than the goal gradient, since it depends upon the development of higher level and more delicate symbolic processes. We also know from other work (**10**) that, in a series of trials given in any one day, the goal gradient is more prominent in the early trials of the series and the anticipatory gradient is more likely to be seen in the later trials of the day.

For these reasons it seemed advisable not to lump all of the results together but to treat them analytically so that we might see differences in performance throughout the series of trials of a day and throughout the days of training. The 13-day training period was therefore divided into three sections, days 1–5, days 6–9 and days 10–13. Scores for the days in one section were averaged together for the first trial, second trials, and so on, in succession.

The results are seen in Table I and in Fig. 2. In the table, averages have been given as computed for the three segments of the maze, called A, B, and C respectively. In looking at the values there, it should be remembered that segment A was 9.2 feet and was twice as long as segments B and C which were 4.6 feet in length (true path). In the figure, the number of feet traveled has been taken into account by dividing it with the average time so that the point plotted in each instance is velocity in feet per second rather than time. As a result, a contour of rising slope, going from left to right, is evidence of a *goal gradient*, whereas a contour of falling slope is an *anticipatory gradient.*

Fig. 2 can serve as the basis of the remarks made here since in it the results are more clearly seen than in the actual numbers contained in Table I. First we may consider the records of the normal animals in the left hand side of this figure. In the first five days, all of the contours have a positive slope and therefore show evidence of a goal gradient. The slope is roughly the same for all the trials. In the second five days, however, the first and second trials show a simple goal gradient, but in the last three trials, an anticipatory gradient makes its appearance in ever increasing amount until in the fifth trial there is no evidence of a goal gradient and the whole contour has the appearance of an anticipatory gradient. Just about the same situation is seen in the data for the last four days except that the transition from a goal gradient in the first trial to an anticipatory gradient in the last trial is even more marked.

Turning now to the operated animals, whose performance is illustrated in the right hand side of Fig. 2, we note a much simpler situation. Every single contour in any of the three groups of days is a simple goal gradient without any vestige of an anticipatory gradient. Indeed, about the only trend that can be seen in the data

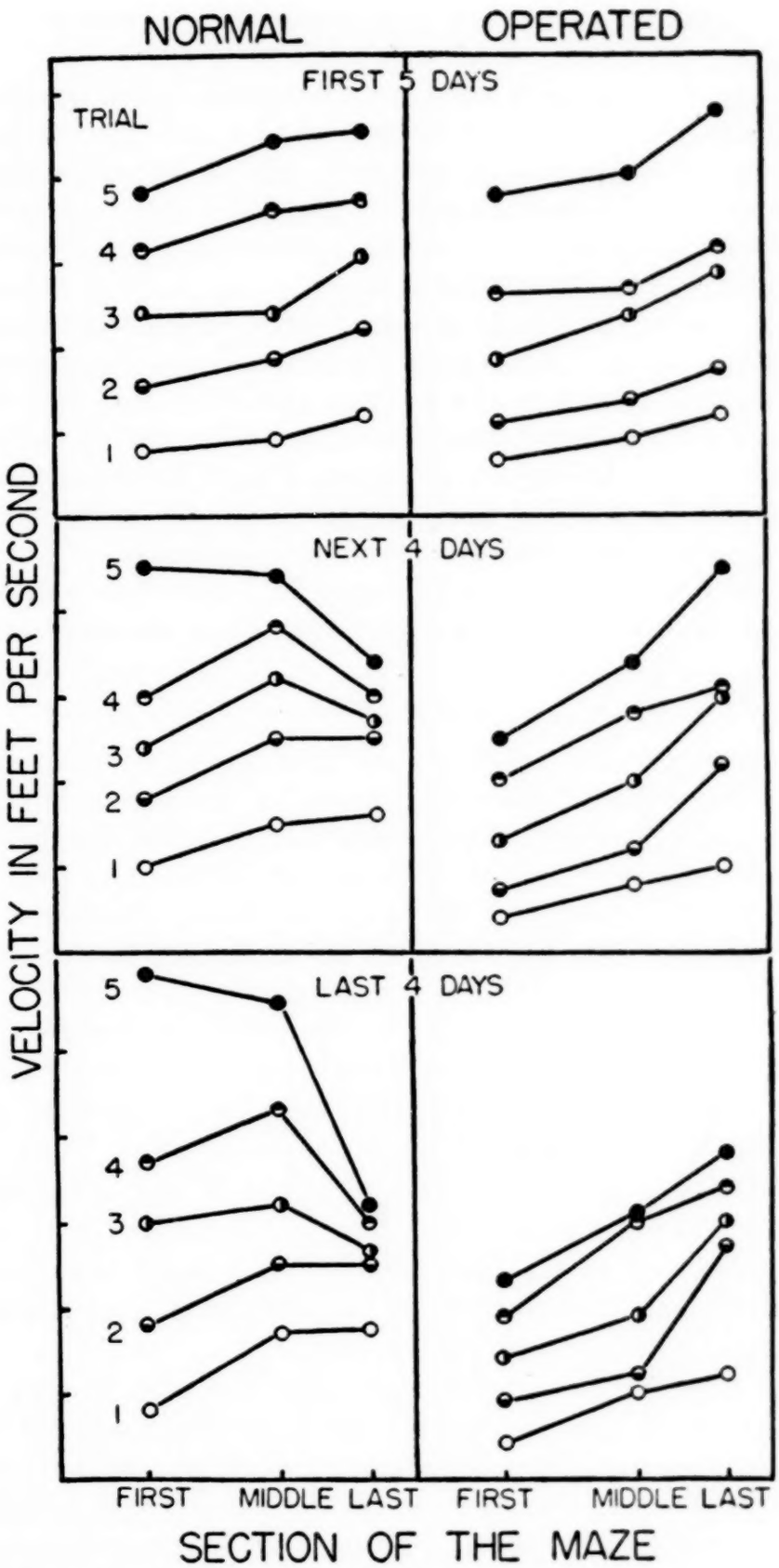

FIG. 2. The performance of normal and operated animals on each segment of the maze on each of five trials given each day, and on the first five days, the next four days, and the final four days.

Each division on the ordinate represents .25 feet per sec. In several cases the curves for later trials are displaced upward in order to avoid confusion, but the normal and operated curves for any given trial are always plotted from a comparable base line so that differences between the two groups can be compared but those between different trials cannot.

A slope upward indicates a trial gradient; a descending slope indicates an anticipatory gradient.

is a tendency for the goal gradient to become more marked as one proceeds from the first to the fifth trial of a group of days or from the beginning to the end of training. Thus, whereas the normal animals develop definite anticipatory gradients throughout the training period and series of trials, no such anticipatory gradients appear in the behavior of the operated rats.

There is one further point of significance which can be seen in the figure and the table. The operated animals are, in general, slower in their running than are the normal rats. In the first five days, there is little difference between them, and what there is is not statistically significant. In the second group of days, however, the normals show a definite superiority over the operates and in the last days of training the difference becomes even more marked. The development of this difference, it can be noted in Table I, is a consequence of the normals improving at a faster rate than the operates.

Discussion

The last mentioned point above, that operated animals do not improve as much as the normal animals in the course of training, is a matter of some interest. One would like to know whether this fact is due to any motor difficulty or to the impairment of psychological functions by the operation. We favor the latter alternative because all of the operated rats appeared to be in perfect health during the training and no evidences of motor disability were noticed. Furthermore, it will be seen that, with the exception of the first two segments of the fifth trial of the last three days, operated animals did as well as normals at some time or other, thus demonstrating that they were capable of the speed sustained by the normal rats. Thus, it seems that the difference in general rate of speed is not a matter of the physical condition of the animals. One might explain it by supposing that, since operated animals appear to be incapable of expectancy of the goal, they lack this element of reinforcement or facilitation for the most rapid running toward the goal.

Turning now to the general significance of the results, we may point out how well they agree with the hypothesis derived from the work on primates and from preliminary work of the same sort with rats. The prefrontal areas in these studies subserve, in large measure at least, the ability to foresee and prepare for future action. Indeed, Freeman and Watts (1), in summarizing the symptoms of their many cases of prefrontal lobotomy, state that inability to foresee the future is the most striking characteristic of these patients. The anticipatory gradient studied here may be taken roughly as the foresight and preparation for the eating of food in the goal box. The total destruc-

tion of this ability in the operated rats has been clearly demonstrated in the results.

There is one serious fault with the data as they stand at present. One would like to know whether similar impairment of the anticipatory gradient might not also follow the removal of other areas of the cortex, and there is no way of answering that from the present study. A later investigation, addressed to this particular point, is necessary before we shall be entitled to draw conclusions about the localization of the anticipatory functions studied here. We have, however, two other studies in which such controls were carried out and other aspects of symbolic processes studied, and in them it was possible to state that the functions showed a differential dependence upon the prefrontal areas. The present work can be taken only as substantiating the hypothesis derived from these other experimental facts.

We would make a suggestion, finally, about the value of psychoneural investigations such as this. The general problem which has usually been raised in the pursuit of research on neural functions in behavior has been whether or not such and such functions are localized in particular areas and if so what areas. Considered in this light, such research often appears to be of little value to the general problems of psychology. Indeed, several writers have asserted that researches which get into the neural functions within the organism have made no contribution at all to the formulation of the laws of behavior (**12**).

In opposition to this view it may be proposed that psychoneural research may contribute to such purely psychological problems by providing a device for the separation of psychological variables, one from the other, in a way not possible in non-physiological investigation. That is to say, by cortical operations, for example, one may sort out, so to speak, behavioral variables that cannot be distinguished in the intact organism because various neural functions are contributing at once to the behavioral phenomenon.

The present research provides a striking illustration for this argument. By the removal of a small amount of tissue in the prefrontal regions of the rat's cortex, we have found anticipatory functions to be abolished without any substantial change in simple goal gradient behavior. Surely then, these two factors in the speed-of-locomotion of the rat are of a different nature, not only in the directly observed differences in the direction of the gradients, but in the kind of functions involved. So far, Hull has treated both the goal gradient and the anticipatory reaction in one general scheme of learning based upon conditioned response principles. Yet a striking separation of the phenomena by means of cortical injury calls, it may be suggested, for an analysis which puts the phenomena at different levels of psychological function. We shall not attempt such an analysis here but

hope that in the future with additional experimental facts of this sort it can be done with profit.

Summary

In his development of a conditioning theory of maze behavior, Hull has postulated a 'goal gradient' responsible for an increase in rate of speed as an animal approaches a goal, and a fractional goal reaction ('anticipatory gradient') considered to underlie a terminal retardation in rate of running which appears near the goal in the later stages of maze training. The first, we thought, involves simple conditioning processes and the second, symbolic processes at a higher level. Since other experiments had indicated that symbolic functions in the rat depend primarily upon the prefrontal areas, the hypothesis was formulated that prefrontal lesions in the rat should abolish the anticipatory gradient, but leave the goal gradient, in the speed of locomotion in the maze.

Eight rats were operated for removal of the prefrontal areas, and 8 normal animals were matched with them in respect of age, sex, and weight. After preliminary training and adjustment to a 24-hour feeding schedule, the two groups were run on an enclosed maze, 18.4 feet long and consisting of 8 right and 8 left turns in single alternation. Five trials a day were given for 13 days. Time was taken on three sections of the maze.

During the first few days (1–5) the normal rats showed a goal gradient throughout all five trials. In the next days (6–9), a terminal retardation (anticipatory gradient) appeared toward the end of the run and especially in the later trials of the day. Then, in the last four days of testing (10–13), the goal gradient tended to be abolished and the anticipatory gradient was operative throughout the whole run. The prefrontal rats, on the other hand, showed a goal gradient in the first few days, just as did the normal rats, but as training was continued, the goal gradient became even more pronounced and there was no sign of an anticipatory gradient.

The experiment confirms, moreover, the hypothesis that the fractional goal reaction in maze behavior involves symbolic processes, and that such processes are mediated by the prefrontal cortical areas of the rat. The differential effect of cortical lesions upon goal gradient and anticipatory gradient points to the conclusion that different types of psychological function are reflected in these respective gradients. The results were presented as an illustration of the way in which psychoneural investigations can contribute to learning theory by the sorting of behavioral functions into classes in a way not possible in behavioral studies alone.

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SIZE CHANGES IN REMEMBERED FIGURES

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The trace hypothesis as advanced by Gestalt theorists to account for memory phenomena has resulted in a number of experiments which seem to show that some changes occurring in trace systems are produced by the internal organization of the traces themselves (autonomous changes). Changes in shape are usually considered as examples of autonomous changes, but it has been suggested that size changes may be due to the same cause (**1**). According to the hypothesis different trace patterns will undergo different distortions over a period of time, and the nature of the distortion will depend upon the inter-relationship of all parts of the trace system which was originally formed.[1] Further, perception of figures with different dynamic properties should result in trace systems with correspondingly different properties, and reproductions based on these systems should manifest different degrees of alteration. It is the purpose of this paper to report an investigation of the changes in size which are found in the reproductions of visually perceived figures.

Some investigators have noted a shrinkage in the sizes of delayed reproductions as compared with the original figure, while others have found that the size increases. Baldwin and Shaw (**2**), in an early experiment, exposed large squares to students in a classroom and required reproductions after intervals ranging from a few seconds up to 40 minutes. They found that the students' drawings were almost always too small. Warren and Shaw (**8**), however, found evidence to suggest that the 'memory image' expanded over periods up to half an hour.

In the investigations of Paula Meyer (**6**), subjects were asked to reproduce a series of figures which had been exposed 24 hours previously. She found that large figures (40 mm. in height) tended to decrease, while small figures (10 mm.) tended to increase when remembered and noted that these tendencies were more marked in children than in adults. Outlining the figures in red produced more accurate reproductions with a consequent diminution in the amount

[1] Alterations can also take place as the result of interaction between two or more trace patterns. In this connection it should be pointed out that some investigators have exposed more than one figure to a subject during a single session and have thus opened the way to effects produced by forces originating outside the pattern under study.

of shrinkage or expansion. Individual differences were so great, however, that Meyer felt no general conclusion could be drawn as to the factors which were influential in size changes. Since she made no attempt to determine the reliability of the changes which she did observe, her findings are of doubtful value.

Perhaps the most striking evidence of size changes has been provided by Allport (1), who presented the Binet key and pyramid designs to 350 school children. The subjects viewed the figures for 10 seconds during class and drew reproductions immediately, after two weeks, and again after four months. The clear-cut character of his results is indicated by the fact that a decrease in size was found in 73 percent of the initial reproductions of the pyramid and in 92 percent of those made after two weeks. The corresponding percentages for the key design were 66 and 73. Changes in size were recorded only when the reproductions were marked by an increase or decrease of at least 20 percent as compared with the original figure. In commenting on his results Allport adopted the position that shrinkage was one of the dynamic properties of traces. He states (1, p. 147): "Unquestionably the stimulus-material itself largely conditions the changes that occur in the image. For example, the designs in the present study were accompanied by marked shrinkage in the successive reproductions, whereas neither Wulf nor Gibson using much smaller stimuli report such a change. The work of Meyer has already shown that this phenomenon of shrinkage stands in some ascertainable relation to the dimensions of the stimulus-figures." The area of the designs in Allport's study was somewhat larger than those used by other workers, but one should also consider the possibility that the traces of the perceptual framework in which the figures were exposed may have acted on the traces of the figures.

An important methodological variation was introduced by Tennies (7), who utilized tactual perception. He presented six figures to blind and sighted subjects and tested retention by presenting the original figures after intervals of 5, 15, and 30 minutes, and 7 days. His results show that both blind and sighted subjects, after 7 days, judged the area of the circle to be larger than it was when originally presented. The conclusion is that the traces of the figure have been shrinking during this period. In the case of the open triangle the results were not so definitive. No clear trend toward expansion or contraction could be found with blind subjects, but sighted individuals reported that the triangle seemed smaller after a lapse of time. Tennies concludes (7, p. 38): "From the results of the present study it can be concluded that figures are apt to become 'better' in the memory image, but that the direction of change toward shrinkage or expansion of the memory image cannot be predicted."

The confusion which exists in previously reported findings points to the need for a systematic investigation of factors which affect size changes. It is desirable to compare the reproductions of figures which have been varied in a planned fashion and to present these figures under conditions which will allow autonomous changes to show themselves as distinctly as possible. Since the analysis of variance is well suited to such a study, the investigation to be reported was so designed that such an analysis could be made.

The figures chosen for exposure were 'stable,' in order to avoid qualitative changes such as pointing and leveling. The factors varied in the designs provided—on the basis of Gestalt principles—different patterns of internal organization. They were: (1) The presence or absence of a circle around the figure; (2) the use of a solid or an outline figure. The significance of these factors will be discussed later.

Apparatus and Subjects

1. *Figures.*—Four figures were drawn in india ink on white cards about 75 cm. square. Figure A was an outline isosceles triangle with a base of 35 mm. and a height of 30 mm. Figure B was the same except that a circle with a radius of 50 mm. was circumscribed about the triangle. Figure C differed from figure A in that the center of the triangle was solidly filled in with black, and for figure D a circle of 50 mm. radius was circumscribed about the solid triangle.

2. *Apparatus.*—The figures were exposed behind a partition containing a viewing aperture so placed that the subjects could not see the edges of the card nor any part of the easel which supported the card. The aperture was constructed by cutting circular holes 47 mm. in diameter in two pieces of cardboard and placing the cardboards 70 mm. apart, one on either side of an opening cut in the partition. The distance between the eye placed at the opening and the exposed figure was 450 mm. With the stationary eye, the white field subtended a visual angle of approximately 27° 56′, and the base of the triangle subtended an angle of 4° 27′. The illumination was furnished by a ceiling lamp in a diffusing globe and was homogeneous over the field. A simple shutter between aperture and figure permitted the experimenter to limit exposures to 10 seconds.

3. *Subjects.*—Thirty male and 34 female college students were assigned randomly to 4 groups of 16 subjects each, so there would be a group to observe each figure. The subjects were in their second or third college year and had never taken part in experiments on visual memory.

Procedure

Subjects were brought into the experimental room one at a time and were given the following instructions to read:

> This is an experiment on the accuracy of observation. You will be shown a triangular figure for a few seconds and will then draw what you have seen from memory. When you are shown the figure, observe it carefully, for you are to make your drawing as nearly like the triangle as possible. Remember, your drawing should be accurate with respect to size, shape, and position. As is customary in psychological experimentation we should like to have you refrain from discussing the nature of the experiment with anybody else until you are told you can do so. If other people are told what to expect, the purpose of the experiment will be defeated.[2]

The subjects were then told to look through the viewing aperture, and the figure was exposed for 10 seconds. They were asked to make a drawing of what they had seen as soon as the exposure

[2] The author wishes to acknowledge the generous aid of Mr. Benjamin Bernstein in collecting the data.

was finished. In the case of those who viewed cards other than A, instructions were given to draw only the outline of the triangle, but 9 of the 32 subjects who had seen the circle drew it, and 5 of the 32 who had seen the solid triangle filled in the center of their figures.

Two weeks later, without warning, the subjects were asked to draw the triangle again. Both immediate and delayed reproductions were drawn on white paper measuring 8.5 by 11 inches.

The base and height of each triangle were measured, and areas were computed in square millimeters. Since the lines drawn by the subjects were not perfectly straight, the values for the areas are approximate. The regularity of the drawings was sufficient, however, to yield results which are not greatly in error.

Results

A general survey of the results is given in Table 1. The mean area of the immediate reproductions is smaller than the area (525 sq. mm.) of the original triangle for every group. The smallest decrease (76.3 sq. mm.) is found in group C, which observed the solid black triangle on a white ground. This result is striking in view of the fact that the apparent size of figures is decreased when black figures are used.

TABLE 1

Mean Difference in Area (sq. mm.) Between Original Figure and First Reproduction and Between First and Second Reproductions for Each Group

Comparison	Group			
	A	B	C	D
0 vs. 1	−127.9	−86.4	−76.3	−111.2
1 vs. 2	58.0	67.3	92.9	10.3

The second line of the table shows that, for every group, the mean area of the delayed reproductions was larger than that of the immediate reproduction. Again the results for group C stand out, since they are the largest of the mean areal increases. The only trend shown in the table is that the two groups having the largest initial shrinkage (A and D) have the smallest increases in the delayed reproduction.

In order to test the effect of the differences in the figures upon the areas of the immediate reproductions, an analysis of variance was performed. The results are summarized in Table 2. The two types of figure (outline or filled) account for one degree of freedom; the presence or absence of a surrounding circle accounts for another; a third is to be attributed to interaction. The appropriate test for error in this analysis utilizes the within-groups variance. It is clear that, since the variances estimated from the effect of the experimental variables and their interaction are all smaller than the within-groups variance, the values of F do not reach the required levels of signifi-

TABLE 2

ANALYSIS OF VARIANCE OF THE AREAS OF IMMEDIATE REPRODUCTIONS

Source	df	Sum of squares	Variance
Surrounding	1	175.56	175.56
Figure type	1	2,862.25	2,862.25
Interaction	1	23,409.00	23,409.00
Within groups	60	7,187,073.37	119,784.55
Total	63	7,213,520.18	

cance. We are forced to conclude, therefore, that the variation introduced by the differences in the figures is no larger than would have been expected from a consideration of the fluctuations found in random samples.

Having found that the means of the sub-groups do not differ significantly, we may combine the sub-groups in order to test whether the mean area of the immediate reproductions is reliably smaller than the area of the original figure. The mean area of all initial reproductions is 424.53 sq. mm., and the standard error of this mean is 42.29. Assuming the true mean to be 525 sq. mm. (the area of the original figure), we can apply the *t*-test. This procedure yields $t = 2.13$, which is significant at the 2 percent level. With considerable confidence, then, we can say that the mean area of the immediate reproductions is smaller than that of the exposed figure.

Out chief interest lies in the differences in the areas of the first and second reproductions, for they are to be attributed to autonomous trace changes. The difference in area was computed separately for each subject, and these values were subjected to a variance analysis. Table 3 presents the summary of the results. Again the within-

TABLE 3

ANALYSIS OF VARIANCE OF CHANGES IN AREA BETWEEN FIRST AND SECOND REPRODUCTIONS

Source	df	Sum of squares	Variance
Surrounding	1	21,480.56	21,480.56
Figure type	1	1,216.50	1,216.50
Interaction	1	34,466.09	34,466.09
Within groups	60	3,030,174.45	50,502.90
Total	63	3,087,337.60	

groups variance is larger than those to be tested against it, so we may conclude that no differences between the four groups exist which may be attributed to the differences between the exposed figures.

Combining all groups, we find that the overall mean increase is 57.13 sq. mm. with a standard error of 27.64. If we assume that this

mean is drawn from a population where the true increase is zero, the application of the *t*-test yields a value of 2.07, which is significant at the 5 percent level. The evidence thus favors the belief that there was a real increase in the mean area of the second reproductions as compared with the mean area of the immediate reproductions.

Since no reliable differences were found among the four groups when areal changes were considered, it seemed worth while to analyze the variance of the changes in height and in size of base. Again, however, no reliable differences appeared which could be assigned to the effect of the figures used.

One other finding should be mentioned. The correlation coefficient between the area of the immediate reproductions and those of the delayed reproductions is .88. This value is somewhat too high because of the effect of two cases which showed extremely large changes, but we do not doubt that there is a strong tendency for subjects who made small initial drawings to make small delayed reproductions and for those who made large initial figures to produce large figures after an interval of time.

Our results may be summarized by saying that although the initial reproductions were smaller than the original figure and the delayed reproductions were larger than the immediate ones, there is no evidence that figural characteristics of the kind employed in this investigation affect these changes. Furthermore, the differences among the exposed figures were not related to differences in changes of the linear dimensions of the reproductions.

Discussion

In the interpretation of our results a critical question is whether or not there are *a priori* grounds for believing that the four figures differ from one another in internal organization. Of course, the answer could be given that since the figures are not identical configurations there are bound to be differences in the forces of organization within them, but this statement is only a superficial appeal to Gestalt principles. Besides, it should be remembered that all the figures were 'stable,' so that in the sense of balanced distributions of forces the figures were very much alike. Nevertheless the figures do differ in important ways, and it is to the specification of these differences that we now turn.

It is hardly necessary to argue the point that, for Gestalt theory, figural regions have different characteristics from the grounds on which they lie. One of the differences is indicated by Koffka (**4**, p. 193): "Then if we have a small figure on a large ground it follows that the *density* of energy must be greater in the figure than in the ground, proportional to the ratio between the ground and the figure

area." (See also **3**, pp. 45 ff., and **5**, p. 84.) The figures used in the present study consisted of one pair of triangles which appeared on large white grounds and of another pair (B and D) which were surrounded by circles. If the circles be thought of as figures, it is clear that the triangles on cards B and D must have been surrounded by a region of higher energy density than was the case with the other figures. It is also likely that the energy density within the triangles was greater in the B and D figures.

Is there reason to believe that these energy-density differences should affect the reproductions with respect to size? An affirmative answer is supported by the work of Köhler (**5**) on the after-effects of long fixations. Among other things he found that if a test figure was thrown on a retinal area which had been stimulated just previously by an outline figure, the test figure was perceived as smaller than normal, *provided the test figure was within the retinal boundaries of the figure used for prior stimulation.* Köhler says (**5**, p. 93): "What has been shown is merely that the size, the location within the third dimension, and the brightness of test objects *within* figures are altered in comparison with the corresponding characteristics of the test objects outside." If differences in excitation pattern during perception produce comparable differences in the trace patterns which they leave (an assumption utilized by most Gestalt theorists), then we should have expected to find differences in the reproductions of the four figures in the present study. No such differences were found.

There is another feature of our figures which should have produced differences in the reproductions: brightness differences. Triangles A and B were segregated from the surrounding field by only a thin black outline; the interiors of the other two were solidly filled with black. This difference should have produced a difference in excitation, which would, in turn, reflect itself in the trace systems. Köhler, speaking of the current which pervades the figure and ground regions, says (**5**, p. 79): "The intensity of this current will depend upon the brightness difference between the figure and its environment." If the outline figures in the present study did not have the same intensities as did the solid black figures, the inequality must have been too small to produce effects or energy differences are totally irrelevant to size changes.

The fact that wide individual differences in size changes were found in our results and were also reported by Meyer deserves attention. The standard deviation of the distribution of changes in area from the first to the second drawings was 221.3 sq. mm., or nearly half the size of the exposed triangle. In view of the similarity of the conditions under which the exposures were made, one would hardly expect this much variation if the alterations were due to internal

changes in the trace pattern. Perhaps recall does not depend upon the trace pattern of the perceived figure but, as some theories suggest, is purely a matter of reconstruction. In that case it would be hard to explain the high correlation which exists between the successive reproductions.

It is hard to know when one has fairly applied the notions advanced by Gestalt theorists to his own data, but we have tried to utilize appropriate principles in proper ways. If we have succeeded, our discussion thus far leaves us with the conclusion that changes in figure area are not to be attributed to autonomous trace changes.

It is possible, however, to account for most of our findings by searching beyond the internal organization of the figure. Koffka (4, p. 474) refers to Hollingworth's study of the 'central tendency of judgment,' and points out that this phenomenon shows the action of an aggregation of traces on each newly created trace. In the case of our subjects, the judgments of size must have been relative to some standard which they carried about in the form of trace aggregations produced by the perception of previous triangles. Such 'class traces' could easily differ from individual to individual as far as size judgment was involved. If, now, these class traces affected the newly formed traces of our figures, in some persons a shrinkage would result, and in other cases expansion would occur. Since the experience of persons with triangles is usually confined to a limited size range, it could be predicted that figures at either end of the range should undergo size changes which would tend to bring them toward the standard or 'class trace' of the individual. Thus large figures should shrink and small figures should expand, not because of autonomous changes, but because of the effect of an 'outside' trace system. Since, in any one subject, the 'class trace' involved remains fairly stable, once a newly formed trace has been altered by this aggregate, large changes are not likely to occur later. Then, as we found, there will be a sizeable correlation between successive reproductions.

Although the explanation we have just outlined fits our results better than the view that size changes are autonomous, serious defects remain. One is the implicit assumption made by most investigators that the reproduced figure is a reasonably good indicator of the state of affairs within the traces. For some subjects nothing could be further from the truth. Consider the unsure, hesitant individual who approaches the act of drawing with considerable timidity. Here size decreases may reflect certain characteristics of the personality rather than changes in the trace systems of the figures. This example illustrates only one of the possibilities for ego-involvement in the act of reproduction, but it should serve as a caution against over-intellectualized interpretations of the remembering process.

Summary

Four figures, constructed so as to vary ground and brightness, were exposed for 10 seconds. Sixteen subjects viewed each of the figures and were required to make an immediate reproduction and another after two weeks. The linear dimensions and the areas of the reproductions were subjected to an analysis of variance. Results were as follows:

1. No significant differences were found among the initial reproductions of the four figures, but a reliable decrease in mean area of all reproductions as compared with the original figure area was found.

2. No significant differences in areal change were found among the four kinds of reproductions when initial drawing was compared with delayed drawing. There was, however, an increase in the mean size of all reproductions which is significant at the 5 percent level.

3. For the 64 subjects, area of first reproduction correlates with area of second reproduction to an extent represented by $r = .88$.

The hypothesis that size changes are autonomous is shown to be incompatible with these results, and it is suggested that 'outside' traces which form the basis for judgments of size are responsible for the changes found in this study.

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AN EXPLORATORY STUDY IN THE PSYCHOLOGY OF SPEECH RECEPTION[1]

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I. Introduction

In the past, language behavior and materials have been treated by psychologists mainly as adjuncts to research in other fields of interest such as those of the thought processes, intelligence testing, child development, social psychology, et cetera. This study is based on the belief that human language can be investigated as a type of functioning of humans in specific behavior situations, and that out of this investigation can be accumulated a systematic body of knowledge concerning human language activity in all its phases. A study of more complex behavior invariably engages one in a consideration of language activity, and yet there exists only a small body of data within the province of psychology itself which deals directly with language problems. On the other hand, students of language outside the field of psychology have usually been content to ignore psychological factors in language or to fit their conceptions into the psychological fashion of the time.

There are two aspects to spoken language which can be handled separately and which are best formulated by means of these two queries: (1) What happens when a person speaks? and (2) What happens when a person listens to speech? The first we shall call speech transmission and the second, speech reception. This study is concerned mainly with the latter.

The psychological problems of speech reception can be divided into the following categories: (1) the action of the person responding to the speech, (2) the conditions under which the speech is received, and (3) the nature of the speech itself. In addition we have, of course, the physiological problems of hearing mechanisms and the physical problems of analysis of complex sound waves and sound propagation. This study is concerned with the second and third of the psychological problems.

Language theory has been enriched by contributions such as those of Buhler (3), Bloomfield (1), and Kantor (11); and there has been

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an increasing experimental contribution to the psychology of language from such sources as Carmichael, Hogan, and Walter (4), Esper (8), and Foley and Cofer (9). We might also mention as relevant to the present study experimental work in the field of visual-auditory presentation modes made by Münsterberg and Bigham (16), Kenzies (12), Elliott (7), and others. Pertinent also are educational studies comparing the teaching efficiency of motion picture plus verbal commentary with presentation of film alone, or with verbal instruction alone. Experimental work in this field has been reported by McCluskey (14), McCluskey and McCluskey (15), Einbecker (6), and others.

II. Experiment I

A. Problem and Procedure

For purposes of experimentation the following terminology and classification have been used. A concrete language situation is defined as one in which the subject, in order to achieve a certain end, must respond not only to speech but also to something else which is related to the speech and which is present in the situation. For example, if you were to ask someone a question concerning a book lying on the table, he might have to examine the book first before he could answer the question intelligently. The person's answer is here conditioned not only by the speech but by a related and necessary activity as well. A remote situation is one in which the person does not need to make a direct perceptual or manipulative action of the things being talked about.

The first experiment was designed as a partial test of the hypothesis that it is easier for a subject to respond to a concrete language situation when both the speech and the things referred to are presented at the same time than when the things referred to are presented at the close of the speech. Ease of response is taken to mean both response times and number of errors.

The experimental set-up was designed to permit the presentation of speech and slides to a subject concurrently and successively. The electrical apparatus and wiring for this have been described in detail in a previous article (2). It consists essentially of a phonograph, an exposure apparatus, and a timer which are coördinated by means of a relay circuit containing a cold cathode gas triode tube so that the initiation of the speech from a phonograph record will start a timer and expose a slide to the subject.

The speech consisted of statements about the exposed slides which could be answered true or false. Before the subject are two telegraph keys marked 'true' and 'false,' and the subject responds by pressing one or the other of these keys. In this way the two stimulus variables of a concrete language situation, the speech and speech referents, are brought under experimental control.

The speech was recorded and reproduced through a loud speaker system to insure the same clarity and speed of pronunciation for each subject. Although this method introduces some element of artificiality into the situation, it was hoped that this would be compensated for by the increased precision gained. The sentences were spoken in a normal fashion by a male voice,

no effort being made to speak too slowly nor to enunciate the words in a 'dictionary' manner. Each sentence was preceded by a ready signal on the record and after each trial there was a lapse of 20 to 30 sec. during which the experimenter recorded the results of the trial. The phonograph records were made at the radio studio of Indiana University, and each record could be used only a limited number of times before deterioration of the surface set in.

The speech referents consisted of slides prepared from dark gray cardboard which were inserted in the exposure apparatus. This apparatus consisted of a black tin box with a frosted glass screen in front and a light bulb inside the box. In back of the frosted glass screen was a square of plain glass with just enough distance between it and the frosted glass to allow for the insertion of a slide. Since the interior of the exposure box was painted black, it was in almost total darkness when the bulb was not lighted. Thus, by arranging carefully the amount and direction of light falling on the exterior surface of the frosted screen, it is possible to keep the inserted slide totally invisible until the moment of exposure. When the light inside the box is turned on the contents of the slide spring into bright relief on the frosted screen. In this way the time of exposure of the speech referents can be controlled by the manipulation of a light switch, or, if it is desired to have the slide appear at the same time that the speech on the phonograph record starts, the light may be turned on by a cold cathode gas triode tube circuit (2).

If it is desired to introduce the slides at the close of the sentence instead of the beginning, the experimenter must turn on the light in the exposure box by means of a separate switch. The experimenter practiced doing this just as the last word was being spoken so that the subject could respond to the slide without any delay. It was desired that there be no interval of time between the end of the sentence and the presentation of the slide, and any cases where this happened were noted and excluded from the results.

In order to test whether presentation of speech and slides simultaneously and successively would result in dependable differences in speed and accuracy of response, a series of ten sentences was recorded and a set of ten slides to match them was prepared. These are shown in Table I.

TABLE I

List of Sentences Used in Experiment I

Sentence	Correct Response	Slide
1. You now see a four, five, and seven	True	4 5 7 F
2. The letter 'F' is over an 'H' and a 'C'	False	H N
3. The number two is between the five and four	False	2 4 5
4. Now you see a three and four	True	3 4
5. A square is between a cross and circle	False	+□△
6. You now see a five, one, and four	True	5 1 4
7. The number seven is between the three and two	True	3 7 2
8. The letter 'F' is between the 'E' and 'G'	False	E G F △
9. The square is above the triangle	False	□
10. The triangle is between two circles	True	○△○

All subjects were carefully instructed in what they were to do and were allowed a practice series in which to become habituated to the apparatus and procedure. For one group of subjects, sentences 1–5 were presented concurrently with the slides and sentences 6–10 with the slides appearing at the close of the speech. For the other group, the procedure was reversed so that sentences 1–5 were presented with the slides appearing at the close of the speech and sentences 6–10 vice versa. Thus, for each sentence there is a set of time readings for simultaneous presentation and one for successive presentation. The following shows the schema.

	Sentences 1–5	Sentences 6–10
Group 1	Simultaneous	Serial
Group 2	Serial	Simultaneous

The subjects sat directly in front of the exposure box with one hand placed on each telegraph key. The key to the left was labelled 'True' and the key to the right 'False.' Subjects were instructed that if they lost track of the sentence or did not understand, they were not to respond at all but were to wait for the next sentence. Cases of no response and of wrong responses were

treated as errors. Times for wrong responses were not included in the time data. All instances in which the cold cathode tube began to discharge too early or too late were noted by the experimenter on the data sheet and eliminated from the results.

B. Results

The average response time and total errors on each sentence are presented in Table II. This response time includes the interval from

TABLE II

AVERAGE TIME IN SECONDS AND NUMBER OF ERRORS ON EACH SENTENCE FOR CONCURRENT AND SERIAL PRESENTATION

Sentence	Ave. Time Ser.	Ave. Time Con.	Diff.	Total Errors Ser.	Total Errors Con.	No. Cases Ser.	No. Cases Con.
1.	3.66	3.23	.43	2	1	17	15
2.	4.18	3.16	1.02	0	3	19	14
3.	3.85	2.74	1.11	3	0	16	16
4.	2.71	2.20	.51	0	0	18	16
5.	3.82	2.69	1.13	6	2	12	12
6.	3.63	2.80	.83	0	0	13	17
7.	3.56	2.71	.85	0	0	14	19
8.	3.31	2.37	.94	3	1	9	18
9.	2.40	1.67	.73	4	0	12	19
10.	2.52	1.74	.78	2	1	14	18
Ave.	3.36	2.53	.83				
Ave. True Statements	3.22	2.54					
Ave. False Statements	3.51	2.53					

the beginning of the sentence until the subject pressed one of the keys. Each group included 19 subjects, although this number was reduced on specific sentences due to elimination of data spoiled by uncontrolled factors. Thirty-eight subjects were used in all.

The time readings for simultaneous presentation are uniformly shorter throughout the ten sentences, the average for the serial presentation being 3.36 sec. and for concurrent presentation 2.53 sec. These calculations are based on the average time for each sentence rather than for subjects. The average difference is a little over .8 sec. and the *t*-value for this is about 3.7. For nine degrees of freedom this surpasses a .01 criterion.

The total errors for each mode of presentation are small, indicating that the task was relatively easy for the subjects or else that they tended to sacrifice time in order to gain greater accuracy. For serial presentation the errors ran about 12 percent of the total trials and in the concurrent about 4.5 percent. The difference of these percentages over the sigma of the difference yields a ratio of approximately 2.5. Thus, the total errors appear significantly fewer for concurrent presentation.

Verbal reports obtained from the subjects afterwards indicate that 23 of them said the serial presentation was more difficult, one said the concurrent was more difficult, and 4 reported equal difficulty.

C. Discussion of Results

The use of a language situation in which it is necessary for the subject to make a perceptual verification of the referent of the speech by looking at a slide enables us to test within limits the speed with which language refers the individual to things. Kantor (11) has proposed that language responses represent simultaneous adjustments to the speech and the speech referents. This he contrasts to a symbolic situation in which the person responds *seriatim* to the sign and then to the significant.

If we assume that the subject's perception of the contents of the slide and the key pressing are results of the kind of adjustment or 'orientation' which the language has induced, it becomes possible to test the immediacy with which the adjustment is made. In brief, if the subject's total adjustment is being made as the language is spoken, and not afterwards, then the presentation of the slide at the beginning of speech should cause shorter response times than if the slide is presented at the close of the speech. If, on the contrary, the subject's adjustment proceeds serially, first a recognition of the speech itself and secondly an adjustment to what has been said after speech has ceased, then the presentation of the slide at the beginning or at the end of speech should give similar results. This would be true because in the first case the subject should be prepared to make a perceptual verification at the end of (or even during) the speech itself, while in the second case the subject should still be unprepared for perceptual verification at the conclusion of the speech.

The disparity between the time readings for serial and concurrent presentation indicates that language does have some of the 'immediacy' of action which is claimed for it. Both the average time for the ten sentences and the total errors indicate that the presentation of the slide at the end of the speech serves only as a delaying factor. The subject has adjusted to the particular relationship stated by the sentence while it was being pronounced and is ready to check this with the slide before the formal ending of the speech.

Nothing is known of the speed of perception or the extent of perceptual span under conditions of linguistic reference; hence we can assign no probable values to the amount of time which it takes the subject to make the necessary discrimination of the slide. If an individual is viewing a complex object such as a painting under conditions of linguistic reference, his perceptual discrimination of various

qualities of the object seems to be 'paced' by the speech. First he notices one thing, then another, as these are referred to by the speaker. That there may be a similar 'pacing' effect here is suggested by the amount of difference (.8 sec.) between serial and concurrent presentation. It should be remembered that the subject was never under any constraint to perceive the contents of the slide suddenly. In either mode of presentation, serial or concurrent, the slide remained exposed until the subject pressed a key.

The present experiment throws no light upon the order of response in symbolic behavior. It might be possible to test the nature of the response in a manner similar to that of the present experiment to see whether the serial nature of the action does in fact exist as has been proposed.

The ten sentences can be classified into two groups on the basis of the type of linguistic reference made. Sentences 1, 4, and 6 (Table I) contain a reference of 'presence or absence' of certain objects on the slide. The others are statements concerning relationships existing between objects on the slide. The stated relationships are of two types, a statement of 'betweenness' and one of 'aboveness.' Of this latter relationship group, sentences 9 and 10 are somewhat different from the others (sentences 2, 3, 5, 7, 8) in that a reference of relation is made between only two terms (sentence 9) or between one term and two others referred to collectively (sentence 10). All the others of the group state a relation between one term and two other terms stated individually. Inspection of the time differences on individual sentences between serial and concurrent presentation (Table II) indicates that there is possibly some relationship between the amount of difference and the type of reference. Sentences 1 and 4 show the least difference between the presentation modes—.43 sec. and .51 sec., respectively. Next in order come sentences 9, 10, and 6 with differences of .73 sec., .78 sec., and .83 sec., respectively; and above these three rank all those sentences which refer to relationships among three terms.

The data do not allow us to infer the precise reason for the above. Several alternatives seem possible. The differences may be due to length of sentence and length of time during which the slide was exposed in the concurrent presentation. On the other hand, the differences may be due to differences in complexity of the sentence, the type of reference which is made, or the complexity of the visual discrimination process.

The differences in total errors on individual sentences are too small to permit much analysis. Sentences 3, 5, and 9 show a fairly large increase in number of errors from concurrent to serial presentation, while sentence 2 shows an increase in the other direction.

Sentence 8 shows some increase in number of errors from concurrent to serial although this is less than for the others.

It will be noted that all the above sentences were false statements. This suggests that the false statements are more difficult to evaluate accurately than the true ones. On the other hand, the time differences for false statements are greater than for the true ones, showing that the serial presentation tended to prolong these more than it did true statements. That this could be so is seen from some of the slides for the false statements (Table I) where the subject, if he were looking at the slide while the sentence progressed, might be able to tell that the sentence was going to be false before it was fully stated. From the available data, however, it is impossible to separate the factor of true and false statements from such other things as sentence length, complexity, type of reference, etc., and so it is impossible to evaluate individually the different variables which seem to be operating.

In summary, then, the data seem to indicate that concurrent presentation of sentence and slide in a concrete language situation is more efficient than serial presentation. Quantitative time and error data and introspective judgments of the subjects agree in supporting this conclusion. It is suggested that this is true because the speech pattern tends to refer the subject immediately to the things or relationship which has been stated, and hence his perceptual verification of the slide normally follows more rapidly than serial presentation will allow. Serial presentation operates only as a delaying factor and increases the difficulty of the subject's task. The influence on the data of such things as sentence length, type of reference, complexity of visual discrimination, and truth or falsity of the statement cannot be assessed accurately from the present data, although several possible explanations seem indicated.

III. Experiment II

A. Problem and Procedure

This experiment was designed to compare the two speech reception situations which have been previously defined, the remote and concrete. The difference between them lies in the fact that the subject, in a concrete situation, must respond to a slide as well as spoken language before he can answer true or false. Bloomfield (1) has called the remote situation *displaced speech* and regards it as a childhood development from the concrete naming situation. The mother in talking to the child first associates the word with the actually present referent and then uses the word later in the absence of the referent. Linguists and psychologists generally regard this as a

process in which the word comes to 'stand for' or 'represent' the absent object.

In dealing with the concrete language situation the notion of 'standing for' seems somewhat artificial. Instead, the conception of the language as possessing a definite function, that of directing the subject's attention towards the slide, seems more adequate.

The remote speech situation represents an additional problem but not necessarily a different method of interpretation. The problem consists of discovering and interpreting the changes which are introduced into language by the complete absence of the things referred to. Since in the remote situation the speech variable is the only one to which the subject can make a direct perceptual response, it appears that the speech must assume more importance. To test this the following experiment was devised.

Two series of ten sentences were compiled, one of which was to be accompanied by slides and the other to be general statements about common objects which could be answered true or false. Both series were designed to be relatively simple so as to impose no intellectual task of any magnitude. The sentences were recorded on phonograph records by a male voice speaking normally with no undue emphasis on enunciation. The general set-up and apparatus are the same as for the preceding experiment. Since a remote language situation involves no visible speech referents, the exposure box is omitted in this part.

In order to test the stability of the two situations a certain amount of speech distortion or mispronunciation was introduced into some of the sentences so that the effect of this on time and errors could be determined. The most general statement of the experimental hypothesis would be the following. A concrete language situation is not so easily disrupted by distortion as is a comparable remote situation. As the particular sentences employed here are restricted in type, length, and complexity, the results cannot be taken as a general test of the hypothesis.

The experimental design was as follows. The subjects were divided into two experimental groups. Group 1 responded to sentences 1–5 spoken normally and to sentences 6–10 spoken distortedly. This is true for both the concrete and remote series of sentences Group 2 responded to sentences 1–5 spoken distortedly and sentences 6–10 normally. Words used in the two series were the same or similar. Due to this latter fact it is reasonable to assume that a subject might benefit in either series by having first heard the other. To control this each of the groups was divided into two sub-groups, one of which was put through the concrete series first and the remote series second, and the other group vice versa. Thus, for each sentence in both series we have time and error measures on a group who responded to that sentence spoken normally, and on another group who responded to it spoken distortedly. One-half of each group had had experience with the other speech situation, and the other half had not.

In order to make cross comparisons between the concrete and remote series some degree of uniformity must be achieved in such variables as sentence length, complexity, choice of words, and degree of distortion. The distortion was introduced by replacing one vowel sound for another. Thus, 'circle' might be pronounced 'cărcle,' and 'triangle' as 'trĭngle.' Only key words were distorted, that is, words which had to be understood correctly in order to understand the statement.

All sentences were of a simple declarative form without undue length or grammatical complexity. No subordinate clauses were used. The speech referents were rather homogeneous in nature in both series, consisting for the most part of circles, triangles, squares, and crosses. The list of sentences used in each situation is shown in Table III. Approximately half were false statements and half true.

All subjects were given a printed set of instructions to read before beginning the experiment. The experimenter then went over the procedure again with each subject and explained details of how to use the telegraph keys, how to sit, etc. After this a practice series of five sentences was run to accustom the subject to the procedure and sound of the voice on the phonograph.

TABLE III

SENTENCES USED FOR THE CONCRETE AND REMOTE SITUATIONS OF EXPERIMENT II

Sentence	Correct Response	Slide
Concrete series		
1. You now see a circle	True	○
2. You see a square and triangle	False	△△
3. You now see a line	True	—
		□
4. A cross is above a square	False	△
5. The circle is between the cross and square	False	○+□
6. You now see a circle	False	□
		+
7. A cross is above the line	True	—
8. You see a square and triangle	True	□△
9. A line is between two circles	False	△○○
10. You see two squares and a cross	True	□□+
Remote series		
1. A circle is round	True	
2. A square and triangle both have corners	True	
3. A square has eight sides	False	
4. One cent and two cents make four cents	False	
5. A wagon has wheels	True	
6. A circle is not round	False	
7. Two nickles make a dime	True	
8. A square and triangle both have corners	True	
9. Three cents and two cents make five cents	True	
10. Every square has three sides	False	

No distorted sentences were included in the practice series, and the subject was given no intimation that there would be any distortion in the regular series. It was believed better to allow the subjects to discover this for themselves in order to avoid anticipation and too much preoccupation with the speech itself. After a series had been run the subject was asked how the sentences sounded, whether he had experienced any difficulty responding, whether certain sentences had seemed harder than others, etc. An effort was made to determine how clearly the subjects were aware that they had been 'tricked' by mispronunciation on certain sentences. Verbal reports indicated that this ranged from a non-recognition of any distortion to an instant appreciation of it upon first introduction.

B. Results of Experiment II

Results for the experiment are summarized in Table IV. The average time of response for normal and distorted pronunciations is given in seconds. It should be remembered that this represents the lapse of time from the beginning of the sentence to the final pressing of a key by the subject. The columns of differences in average time between normal and distorted pronunciation for each sentence show that distortion has produced a noticeable prolongation of response time for most of the sentences although this varies widely from sentence to sentence. This is true for both the concrete and remote situations. The average increase for the concrete situation is +.187 and for the abstract situation +.51.

A summary of statistics for the experiment is given in the first part of Table VII. For the normal and distorted pronunciation in the concrete situation, the *t*-value for the difference of +.187 is 3.01. For nine degrees of freedom this satisfies a .02 criterion of signifi-

TABLE IV

AVERAGES IN SECONDS AND NUMBER OF ERRORS FOR EACH SENTENCE OF CONCRETE AND REMOTE SERIES—EXPERIMENT II

Sentence	Ave. Time Normal	Ave. Time Distorted	Diff.	No. Errors Normal	No. Errors Dist.	No. Cases Normal	No. Cases Dist.
			Concrete series				
1.	1.62	1.82	.20	0	1	32	31
2.	1.92	1.93	.01	2	2	33	28
3.	1.66	1.81	.15	0	7	35	25
4.	2.09	2.00	−.09	0	3	35	27
5.	2.43	2.55	.12	3	2	32	27
6.	1.88	1.82	−.06	1	2	29	34
7.	1.96	2.07	.11	3	16	29	19
8.	1.81	2.32	.51	0	6	32	29
9.	2.04	2.40	.36	0	8	32	26
10.	1.78	2.23	.55	0	4	31	27
			Remote series				
1.	1.55	1.84	.29	1	13	24	20
2.	2.95	2.86	−.09	10	6	26	24
3.	2.23	2.29	.06	2	2	31	30
4.	3.07	3.31	.24	1	9	33	23
5.	1.91	2.98	1.07	1	24	35	8
6.	1.81	2.43	.62	6	17	25	17
7.	1.50	2.58	1.08	1	17	31	18
8.	2.87	3.16	.29	5	11	26	24
9.	2.60	3.57	.97	2	20	29	15
10.	2.35	2.87	.52	3	7	27	27

TABLE V

SUMMARY OF STATISTICS

	Ave. Time Normal	Ave. Time Distorted	Diff.	*t*	% Errors Normal	% Errors Distorted	Critical Ratio (%)
			Exp. II				
Concrete	1.92	2.10	.187	3.01	3.0%	10.8%	3.8
Remote	2.28	2.79	.51	3.7	9.8	38.1	9.1
			Exp. III				
Concrete	1.98	1.92	−.06	1.44	9.7	12.3	.85
Remote	2.09	2.44	.196	2.36	9.0	22.0	3.7

cance. The total number of errors increased from 9 for normal pronunciation to 51 for distorted pronunciation (Table VII). The percentage increase in errors is about 8 percent and the critical ratio of this increase is 3.8. Thus, distorted pronunciation gives a statis-

tically significant increase in both time and errors for the concrete situation.

In the remote situation the average difference of +.51 possesses a *t*-value of 3.7. For nine degrees of freedom this satisfies a .01 criterion of significance. The percentage increase in errors is approximately 28 percent and the critical ratio for this percentage difference equals 9.1.

In brief, the introduction of distortion served to disrupt the subject's responses in both language situations but the degree of disruption is much greater for the remote situation. In order to test whether the greater degree of disruption in the remote situation is statistically significant, we may apply a *t*-test for the significance of a difference in the means of small independent samples. The difference over the sigma of the difference yields a *t*-value of 2.45. For 18 degrees of freedom this surpasses a .05 criterion but just falls short of satisfying a .02 criterion. Hence, the greater degree of disruption in the remote situation possesses some statistical reliability, and the results as a whole tend to satisfy the hypothesis that a concrete language situation is less prone to disturbance by speech distortion than a comparable remote situation.

Inspection of average time, normal and distorted, for specific sentences indicates that the tendency shown by the averages is by no means invariable. In some cases there are reversals where distorted pronunciation yields a lower average time than normal. Although this may be due to small numbers and inadequate sampling, it still suggests that the hypothesis holds only for averaged results on matched sentence groups rather than in each specific case. There are also occasions where distortion caused less disruption in a remote sentence than in a concrete sentence. This again suggests that the hypothesis applies to average results predominantly.

IV. Experiment III

A. Problem and Procedure

After a group of 70 college students had been used in Experiment II, it was decided to repeat the experiment using another series of sentences for concrete and remote situations. This was done for several reasons. First, it seemed desirable to use another group of students to check on the reliability of results from the first experiment. Second, a wider sampling of sentences was used, especially sentences which referred to objects other than geometrical figures. It was felt that the sentences of Experiment II had been too homogeneous in their referential objects. Third, the amount of distortion was decreased in order to reduce the total number of errors made and

to diminish the subject's awareness of 'something wrong' with the pronunciation. Fourth, the distortion introduced into the concrete and remote sentences was made more comparable by distorting the same words in an identical fashion. Results from Experiment II had shown that the disruption of response caused by distortion depended upon other variable factors besides the number of vowel sounds that were changed in each sentence.

The list of sentences used is shown in Table VI and the slides accompanying these in Fig. 1. A much wider variety of referential objects is used than in Experiment II, including such things as animals, people, furniture, common household articles, etc. In the concrete series these objects were represented by black pen-and-ink drawings on cellophane slides which were exposed in the same manner as the slides for the preceding experiment. A group of 42 college students was used.

TABLE VI

SENTENCES USED FOR THE CONCRETE AND REMOTE SITUATIONS OF EXPERIMENT III

Sentence	Correct Response	Slide*
Concrete series		
1. The umbrella is open	True	
2. The clock has a pendulum	True	
3. The animal has short ears	False	
4. The blades on this knife can be closed	True	
5. The violin has strings	False	
6. The stool has five legs	False	
7. The cup is placed on a saucer	True	
8. The dog has a long tail	False	
9. The candles are on a Christmas tree	True	
10. The arrow has been shot from the bow	True	
Remote series		
1. Umbrellas can be opened	True	
2. All clocks have pendulums	False	
3. All animals have short ears	False	
4. The blades on some knives can be closed	True	
5. Violins have strings	True	
6. All stools have five legs	False	
7. Cups are placed on saucers	True	
8. Some dogs have a long tail	True	
9. Candles are put on Christmas trees	True	
10. Arrows are never shot from a bow	False	

* The slides for the concrete series are shown in Fig. 1.

B. Results of Experiment III

The results of Experiment III are summarized in Table VII. For the concrete sentences the time difference values fluctuate between positive and negative and the average is −.06 sec. For errors there is a slight increase under distorted pronunciation but not as great as for the preceding experiment. The number of errors committed under normal pronunciation is higher than that for the preceding experiment, a fact which is due perhaps to increased complexity in the slide or to some ambiguity in the drawing of the objects on the slide. The statistics for Experiment III have been summarized in

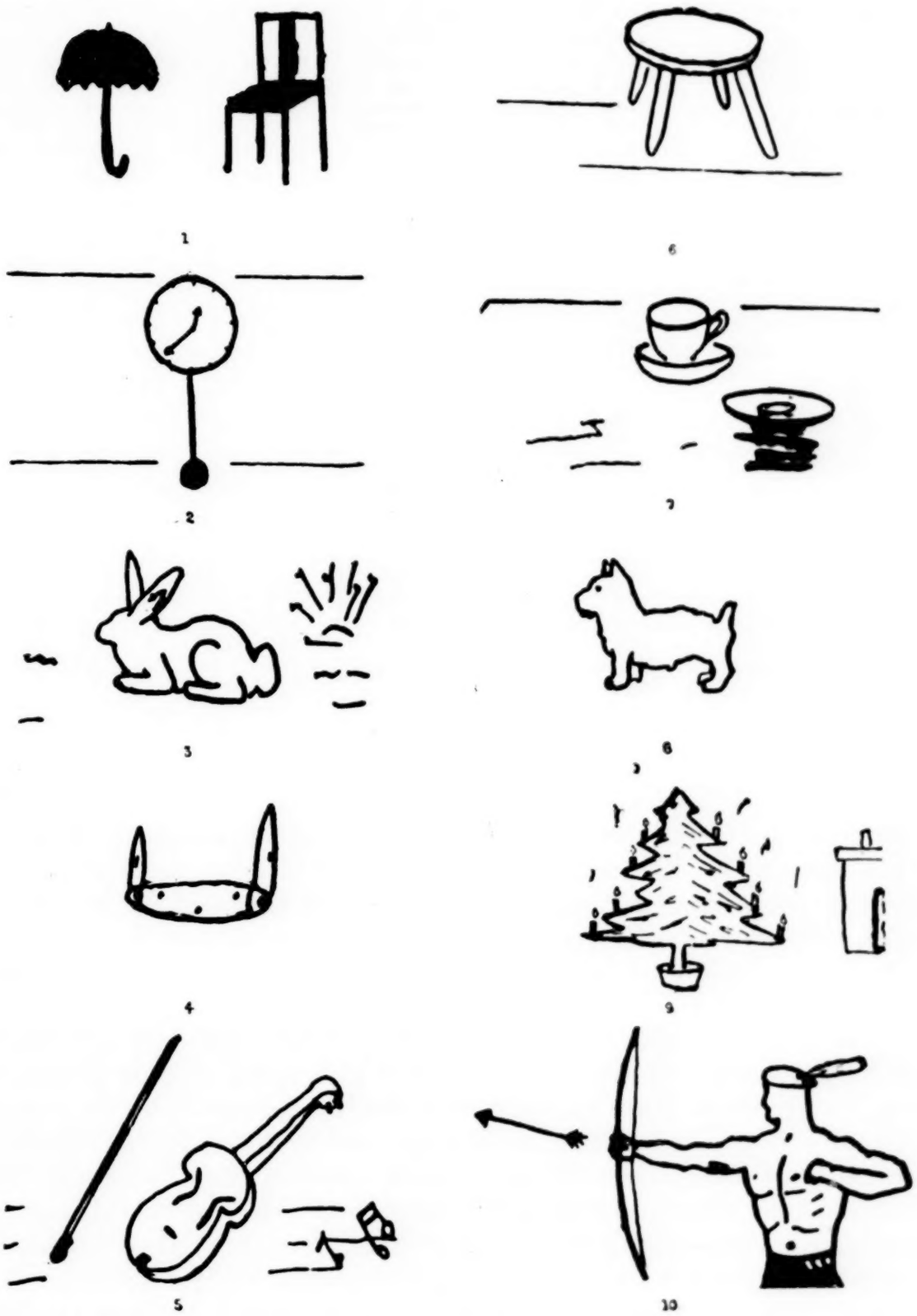

FIG. 1. Slides used in Experiment III.

TABLE VII

AVERAGES IN SECONDS AND NUMBER OF ERRORS FOR EACH SENTENCE OF CONCRETE AND REMOTE SERIES—EXPERIMENT III

Sentence	Ave. Time Normal	Ave. Time Dist.	Diff.	No. Errors Normal	No. Errors Dist.	No. Cases Normal	No. Cases Dist.
			Concrete series				
1.	1.92	1.87	−.05	0	4	20	16
2.	2.08	2.01	−.07	4	5	18	19
3.	1.80	1.85	.05	0	0	21	21
4.	1.90	1.71	−.19	0	3	20	19
5.	1.94	2.04	.10	0	3	20	19
6.	1.62	1.67	.05	2	0	17	21
7.	1.88	1.71	−.17	2	7	19	14
8.	2.04	2.01	−.03	5	3	16	18
9.	2.57	2.23	−.34	1	1	20	19
10.	2.02	2.05	.03	4	2	15	19
			Remote series				
1.	1.87	1.77	−.10	0	2	19	19
2.	2.10	2.67	.57	6	4	12	16
3.	2.29	2.27	−.02	1	7	20	12
4.	2.59	2.54	−.05	1	5	18	15
5.	2.00	2.27	.27	1	11	19	11
6.	2.03	2.46	.43	3	5	14	15
7.	1.99	2.26	.27	3	1	15	20
8.	1.91	2.00	.09	1	1	19	20
9.	1.99	2.31	.32	1	3	19	18
10.	2.10	3.82	1.72	1	18	19	3

the lower half of Table V so they may be compared with those for Experiment II. The negative difference of .06 sec. possesses a low *t*-value of 1.44 and may be accounted as a chance difference. Likewise, the increase of errors by 2.6 percent under distorted pronunciation has a critical ratio of .85 and may be considered as a chance difference.

Six of the concrete sentences of Experiment III had one vowel sound distorted and the other four had two vowel sounds distorted. The results show that this distortion produced practically no disruption of response as measured by time and errors. In the concrete situation of Experiment II there were two sentences with one distorted vowel sound, six sentences with two vowel sounds distorted, and two sentences with three vowel distortions, a total of 20 distortions as opposed to a total of 14 distortions for Experiment III. This amount of reduction in distortion has seemed to lower the disrupting effect to a point where it is no longer of statistical significance in the concrete situation.

However, in the remote situation of Experiment III, distortion of the same words in the same manner has produced an average

increase of .20 sec. in time and of 13 percent in total errors (Table V). The *t*-value for the time difference is 2.36 and for eight degrees of freedom satisfies a .05 criterion.[2] The number of errors for normal pronunciation remains about the same as for the preceding experiment but under distorted pronunciation the rise is less than that for the preceding experiment. This again indicates that the reduction in distortion has produced less disruption of response. The critical ratio for the increase in percent of errors is 3.7, indicating statistical significance for the rise in errors as well as for time.

In summary, the results from Experiment III indicate that the distortion of the same words in a concrete and remote situation has produced no significant disruption of response in the former but has in the latter. Therefore, the conclusions are similar to those of Experiment II, and the experimental hypothesis is again supported.

We may again apply the *t*-test for significance of difference in the means of small independent samples in order to test whether the difference of time results in the concrete and remote situations is statistically reliable. The ratio of the difference over the sigma of the mean gives a *t*-value of 2.42. For seventeen degrees of freedom this surpasses a .05 criterion, but just fails to meet a .02 criterion, of significance. Under customary interpretation, this result taken in conjunction with the similar result from the preceding experiment may be interpreted as giving full statistical reliability to the difference in average response time between normal and distorted pronunciation in a remote language situation as compared to a concrete language situation.

V. Introspective Reports for Experiments II and III

Brief introspective reports from most of the subjects were obtained to determine whether one situation seemed more difficult than the other (see Table VIII). Subjects were asked the question, "Did the distortion of words bother you more in one series of sentences than in the other?" Those who seemed not to realize clearly the deliberate distortion of words were not quizzed very closely on the relative difficulty of the two situations. In analyzing these reports an attempt was made to tabulate the frequency with which one language situation was designated harder than the other. The answers are definitely conditioned by the order in which the subject went through the experiment, because the experience gained on one series tended to help in the other.

[2] In sentence 10 of the remote situation the increase in time and errors under distorted pronunciation was so great that it was decided to eliminate this sentence from the results, in order not to influence unduly the average time and errors for the others.

TABLE VIII

TABULATION OF SUBJECTS' REPORTS TO THE QUESTION, "DID THE DISTORTION OF WORDS BOTHER YOU MORE IN ONE SERIES THAN IN THE OTHER?"

Experiments II and III Combined

Order	Percent of subjects reporting in each category		
	Concrete Harder	Remote Harder	Equal Difficulty
Concrete-Remote Group	38.88%	38.88%	22.22%
Remote-Concrete Group	8.00	80.00	12.00
Averages	23.44	59.44	17.11

In Experiment II about 20 classifiable reports were obtained from subjects who took the concrete series first. Of these, 7 reported the concrete to be harder, 10 reported the remote harder, and 3 reported equal difficulty. Of those who took the remote series first, 24 reported it harder, 1 reported the concrete harder, and 2 reported equal difficulty.

In Experiment III the classifiable reports of those who took the concrete first showed 7 reporting it harder, 4 reporting the remote harder, and 3 reporting equal difficulty. For the group who took the remote series first 16 reported it harder, 3 reported the concrete harder, and 4 reported equal difficulty. Total tabulation showed 54 reports that the remote situation was harder, 18 reports that the concrete was harder, and 12 reports of equal difficulty.

In Table VIII the frequencies of reports for the two experiments have been combined and converted into percentages. Thus, of the subjects who took the concrete before the remote series, 38.88 percent reported the concrete more difficult, 38.88 percent reported the remote more difficult, and 22.22 percent reported equal difficulty. Of those who took the concrete after the remote, 8.00 percent reported the concrete harder, 80.00 percent reported the remote harder, and 12.00 percent reported equal difficulty. The averages for the two combined show 23.44 percent reporting the concrete harder, 59.44 percent reporting the remote harder, and 17.11 percent reporting equal difficulty. With the factor of rotation equalized, the reports still run decidedly in the direction of more disturbance under remote situation distortion than under concrete situation distortion. Thus, the introspective tabulations point in the same direction as the quantitative time and error data.

VI. Discussion of Results of Experiments II and III

The remote language situation used here differs from the concrete mainly in the fact that the individual cannot progress from the lan-

guage to a direct inspection of the things being talked about. Due to this in part is the fact that the style of reference in the remote sentences differs from that of the concrete. To say, "This pen that you see is a fountain pen" is not quite the same as to say "Some pens are fountain pens." Logicians would classify one as a singular proposition and the other as a proposition about classes. Remote sentences may, of course, be of the singular type, such as "The president's pen is a fountain pen."

A proposition about classes is perhaps an intrinsically more difficult one to respond to with an evaluation of true or false. The data indicate that the times for the remote series normally pronounced are somewhat longer than those for the concrete. Although the sentences in the two groups are not exactly matched in length, the amount of difference suggests that the subjects respond more slowly to the remote than the concrete series. The problem for a psychology of language is to find out exactly what happens in each case. Upon this would depend an explanation of the differences found.

The remote sentences represent a more attenuated language situation than the concrete. The organism might be thought of as being in contact with the things talked about only through its past experience. In the concrete the contact is direct. For this reason the speech is less important in the latter case than in the former. The subject is really less dependent upon it. Hence a distortion of the speech bothers him less than it does in the remote sentences. The two language situations used here might be considered as stages in a continuum which extends from those occasions where the language variable is very important to those occasions where it becomes almost wholly unnecessary. Representative of the former are such things as technical scientific description, legal language, or the language of international diplomacy. Representative of the latter are occasions where formal language may be dispensed with, and communication is carried on by means of a grunt, nod, or gesture. In the latter case the 'distortion' of the speech consists in its elimination altogether.

The remote situation of our experiment is towards the upper end of the continuum where the speech becomes more important, whereas the concrete situation belongs more towards the lower end where the speech is less necessary.

Another possible interpretation might be to the effect that the concrete represents a genetically earlier and more stable situation. Bloomfield (1) has spoken of *displaced* speech as arising from concrete naming situations. If this is true, then the concrete sort of situation is an earlier circumstance out of which remote reference is developed.

This interpretation, however, lacks supporting evidence, and indeed the varied language references which adults can make could hardly be traced to an earlier development of this kind. In children the process is often reversed. They will be found making reference to things with which they have had no contact up to that time. Educational programs really foster this type of development. Laboratory courses were introduced into grade schools and colleges as an antidote.

At the beginning of the experiment an attempt was made to evaluate the subject's linguistic background, but this proved to be too difficult a task and so was not continued. Some individuals who actually had a speaking knowledge of two languages were still rather inflexible in their pronunciation and understanding of English. Others who were raised in communities where they encountered numbers of varying accents could stand a certain amount of speech distortion before they failed to understand what was said. In the present study no attempt was made to investigate individual differences in degree of 'resistance' to mispronunciation, although, as has been intimated above, this difference is quite large. In Experiment II, for example, individual averages on the first five sentences of the concrete situation, normally pronounced, ranged from 1.43 sec. to 2.99 sec. For the first five sentences of the concrete, distorted pronunciation, individual averages ranged from 1.70 sec. to 2.21 sec. For the first five sentences of the remote situation, normally pronounced, individual averages ranged from 1.79 sec. to 3.10 sec.; for distorted pronunciation, 2.08 sec. to 3.87 sec. Quite probably there would be correlations with such things as the individual's linguistic history and his general intellectual background.

In the concrete situation of Experiment II, two sentences were repeated (sentences 1 and 6, 2 and 8), one time as a true sentence and the other as a false sentence. This was done as a direct check on any possible difference which might exist between true and false statements. The results were contradictory for the two pairs of sentences and hence no light is thrown on the question. On *a priori* grounds it might seem plausible that false statements, in a concrete situation at least, might have complicating factors not possessed by true statements. This complication could arise in the conflict between the adjustment imposed by the speech and the visual perception of the slide. It seems quite probable that perceptual activity is altered extensively by the conditions of linguistic reference. The author hopes to pursue this line of investigation in future studies.

There might be some tendency to interpret the results of the second and third experiments in terms of purely psychophysical techniques and concepts. It could be said, for example, that the subject

in the concrete situation is responding to a 'greater magnitude of stimuli' (light plus sound) than he is in the remote, and that therefore equivalent distortion produces less effect in the first than in the second. This, however, ignores the specific linguistic character of the situation. Stimuli are classified as 'light' or 'sound' without concern for the particular functions which specific sound or light variables have taken on for the individual during his development. It might be possible to introduce visual stimuli in a concrete situation which would be totally irrelevant to the language, and thereby obtain a reversal of the results of this study. The 'magnitude' of the stimulus would still presumably be the same, but its specific linguistic character would have been destroyed by making it a distractor rather than an essential part of the behavior field.

It should be kept in mind that the results of all three experiments indicate that the simultaneous presentation of two stimulus sources, sound and light, has resulted in a greater efficiency, ease, and stability of response, rather than the reduction in some of these factors which might be expected in an ordinary distraction experiment. We interpret this as indicating that activity directed towards speech referents is an integral part of a genuine language situation, and not merely an added task which has been imposed by laboratory procedure.

VII. Summary

This experiment was a preliminary investigation into some problems of speech reception. The first experiment was designed to determine the speed with which language refers individuals to the things spoken about. The second and third experiments compared two general language situations which are found in every day life in an attempt to determine the relative importance of the speech variable in each.

Experiment I.—A concrete language situation was defined as one in which the individual must make some sort of direct perception of that which is being talked about. A list of ten sentences which referred to various aspects of slides that were being exposed was recorded on a phonograph record and presented to a group of 33 college students of both sexes. The speech was received under two conditions. For one group the slides were presented at the beginning of speech (concurrent presentation), and for the other at the end of speech (serial presentation). Data on time of responses consisted of the total time from the beginning of the speech until the subject pressed a true or false key indicating the truth or falsity of the statement. Other data consisted of the number of errors and introspective reports of the subjects.

Results showed an average increase in time of .8 sec. from concurrent to serial presentation; and errors for the group of subjects increased about 7.5 percent under serial presentation. Twenty-three subjects reported the serial presentation more difficult; one reported concurrent more difficult; and 4 reported equal difficulty.

From this it was concluded that the language functioned more efficiently when the slide was presented along with the speech rather than afterwards. It is suggested that this is so because the individual's adjustment to what is being said takes place very rapidly so that he is in a position to compare what is asserted with the exposed slide while the sentence is being pronounced rather than afterward.

Analysis of individual sentences indicates that the difference between concurrent and serial presentation may vary with such factors as type of linguistic reference, sentence length, complexity of the slide, et cetera.

Experiment II.—The second experiment compared a concrete language situation, as defined above, with a remote language situation in which the individual is not in direct contact with the things that are being talked about. It was desired to find out if distortion of the speech variable would cause a greater disruption of response in one situation than in the other.

Ten sentences, similar to those used in the first experiment, and ten slides were prepared for use. A normally pronounced and a distorted version of each sentence were recorded. Distortion consisted of replacing one vowel sound with another in some of the key words of the sentence. The sentences for the remote situation consisted of general statements which could be answered true or false. The data included time of response, number of errors, and introspective reports. A group of 66 college students of both sexes was used. The chief results were as follows.

(1) In the concrete situation, distorted pronunciation caused a rise of .18 sec. in average length of response. The *t*-value for this difference satisfies a .02 criterion.

(2) Percent of errors for the total number of trials increased about 8 percent under distorted pronunciation, and this increase was statistically significant.

(3) In the remote situation, distortion caused an average rise about three times as great as for the concrete situation. The *t*-value of the difference satisfied a .01 criterion.

(4) Percent of errors for distorted pronunciation increased about three and one-half times that for the concrete situation. This difference was statistically significant.

(5) Introspective reports showed that about 4 out of every 5 subjects reported the distortion more bothersome in the remote situation.

Experiment III.—This experiment was designed as a check on the results from the preceding experiment. The effect of distortion in the two situations was made more comparable by distorting the same words in an identical fashion. The total amount of distortion introduced into the sentences was less than for the preceding experiment. The referents of the sentences were numerous familiar objects depicted on the slides rather than the geometrical figures of the preceding experiment. This was done to introduce a greater variety into the linguistic situation. A group of 42 college students of both sexes was used. The chief results were as follows.

(1) In the concrete situation there was no significant rise in average response time nor in percent of errors under distorted pronunciation. This was probably due to the lower amount of distortion used.

(2) However, distorted pronunciation in the remote series caused an average rise of .36 sec. in length of response. The *t*-value for this satisfied a .05 criterion.

(3) Percent of errors in the remote situation increased 13 percent under distorted pronunciation. This was statistically significant.

(4) Introspective results showed twice as many subjects reporting the remote distortion more difficult than the concrete.

From the results of the second and third experiments it was concluded that the speech variable plays a more important role in remote reference than in concrete reference, since its distortion in the former case created a greater disruption of behavior. It is suggested that the two experimental situations used here are stages on a continuum ranging from those occasions where the nature of the speech variable itself is highly important, to those occasions where it can be dispensed with almost entirely. The nature and importance of speech reception depends upon the psychological situation in which it is received.

This study emphasizes the need for psychological investigation of human language as a distinctive form of human behavior which varies widely under different circumstances. This approach would be distinct from an investigation made by the logician on one hand, or by the phonetician and physiologist on the other. In this way psychologists can categorize the functions of human language and perhaps throw light on problems of individual differences in language functioning and malfunctioning.

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PROBLEM SOLUTION BY MONKEYS FOLLOWING BILATERAL REMOVAL OF THE PREFRONTAL AREAS: III. TEST OF INITIATION OF BEHAVIOR

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I. Purpose

The purpose of the following study was to compare the behavior of monkeys following bilateral destruction of the prefrontal areas with the behavior of normal monkeys in responding to pieces of food briefly presented in an irregular order at one side of the cage or the other. Since the reaction sequence involved in grasping and ingesting food is acquired early in the life of the monkey, this test involved the formation of no new conditioned response, discrimination, principle, concept or insightful relationship. It involved nothing more than being ready to respond and responding to pieces of food briefly presented in the test situation. The test is described as one of initiation of behavior.

II. Subjects

Two operated animals, numbers 54 and 55, and two unoperated animals, numbers 21 and 22, were the subjects in this investigation. The previous history of these rhesus monkeys has already been described in the earlier papers of this series (2, 3).[1]

III. Apparatus

The apparatus was a wooden box 24 in. in length, 10 in. high, and 5 in. deep. A sheet of plywood 12 in. by 24 in. was attached to the top and inclined backwards at a 45-degree angle. The entire apparatus was painted a uniform grey. The front of the box which faced the subject was open, with a floor raised, 2 in. above the base. Upon the floor rested two chrome steel strips 4 in. wide and 15 in. apart center to center, described as food platforms. These strips were inserted through narrow slits in the back wall of the box and could be slid back and forth. A three-eighths in. square strip of wood bounded both sides of each metal strip.

Near the top of each end of the box was an opening 3 in. in diameter, covered with a wire screen. Outside the box, in front of each opening, was a 40-watt light which illuminated the inside of the box and the food platforms. These lights were shielded from the animals by a plywood frame.

* This work was supported in part by a grant from the Special Research Fund of the University of Wisconsin for 1940–41.

[1] Preliminary tests on the problem had already been run on two unoperated rhesus monkeys, numbers 56 and 57. Their data were not included since slight changes in method and in the number of trials at the various exposure intervals were made. These preliminary tests indicated that the one second exposure interval was likely to prove critical and for this reason the number of test trials at this interval was doubled. Animals 56 and 57 made scores very similar to those made by 21 and 22.

In the roof of the box were two holes one-half in. in diameter. These holes were directly over the center of the food platforms when these were pushed fully forward. The experimenter was concealed from the animal by the sheet of plywood attached to the top of the box. Affixed to the middle of the inner side of the inclined plane plywood sheet was a mirror and beneath this was another opening 9 in. long and 3 in. wide in the roof of the box. This device enabled the experimenter to see the hands of the monkeys without being seen by the subjects.

The animals were enclosed during the test-period in a cage similar to that described by Harlow and Bromer (1), with the one-way vision screen and the sliding test tray removed. Throughout the tests, the forward opaque screen was lowered so that the bottom of it was level with the roof of the test box. This served as an additional shield to hide the experimenter from the animals.

IV. Procedure

General procedures:

The general procedure used in each trial was to drop a small piece of orange through one of the holes in the roof of the box upon a food platform. The orange remained on the platform for a predetermined length of time, or until taken by the animal. If the subject did not take the food within the predetermined time interval, designated as the exposure period, the chrome steel strip was retracted, and the food fell through an opening in the floor of the box out of reach of the monkey.

Food was dropped through either hole in predetermined order so arranged that on half of the trials food fell upon the platform previously baited, and on the other half of the trials it fell upon the platform previously empty. Four different trial series of 25 trials each were used and in all of the series the same food platform was baited once for 4 successive trials and twice for 3 successive trials. Each trial began when the food was dropped, and ended either when the monkey obtained the food or at the expiration of the exposure period. Records were kept of the success or failure of the animal to obtain food and of the time from the beginning of the trial to the obtaining of food on all successful trials. Throughout the experiment 6 different time intervals were interposed between trials. Each interval appeared in an irregular order and not less than 4 times every 25 trials. The inter-trial intervals were of 10, 12, 14, 16, 18, and 20 sec. duration. An error is defined as failure by the monkey to obtain food in any exposure interval.

Specific test procedures:

The present experiment was carried out as a series of 6 tests. The specific procedures with reference to number of daily trials, number of days run, and time interval for the exposure periods are described below:

Test 1: Food was left on the food platform for 10 sec., and trials were run until the monkey made no more than 5 errors in the 50 consecutive trials of a two days' run. This test was designed to acquaint the subject with the test situation and the general nature of the problem.

Test 2: Food was left on the platform for 5 sec. The test was completed in two days, 25 trials a day being run.

Test 3: Same as Test 2 save for the fact that food was left on the platform for 3 sec.

Test 4: Same as Tests 2 and 3 save for the fact that food was left on the platform for 2 sec.

Test 5: Food was left on the platform for one sec. The test was completed in 4 days, 25 trials a day being run. Thus the total number of trials in Test 5 was twice that of the total number of trials for Tests 2, 3, and 4.

Test 6: All 5 exposure intervals were presented an equal number of times but in irrgeular order for the 25 trials of a day's run. The test was completed in 4 days and therefore comprised 100 trials, 20 trials each for the 5 different exposure intervals of 10, 5, 3, 2, and 1 sec. respectively.

V. Results

The numbers of failures made by each animal in the first 5 tests are shown in Fig. 1. In interpreting gross number of errors it must

be noted that each monkey ran 100 trials at the one-sec. food exposure interval, and 50 trials at food exposure intervals of 2, 3, and 5 sec. All subjects ran 50 trials at the 10-sec. interval save animal

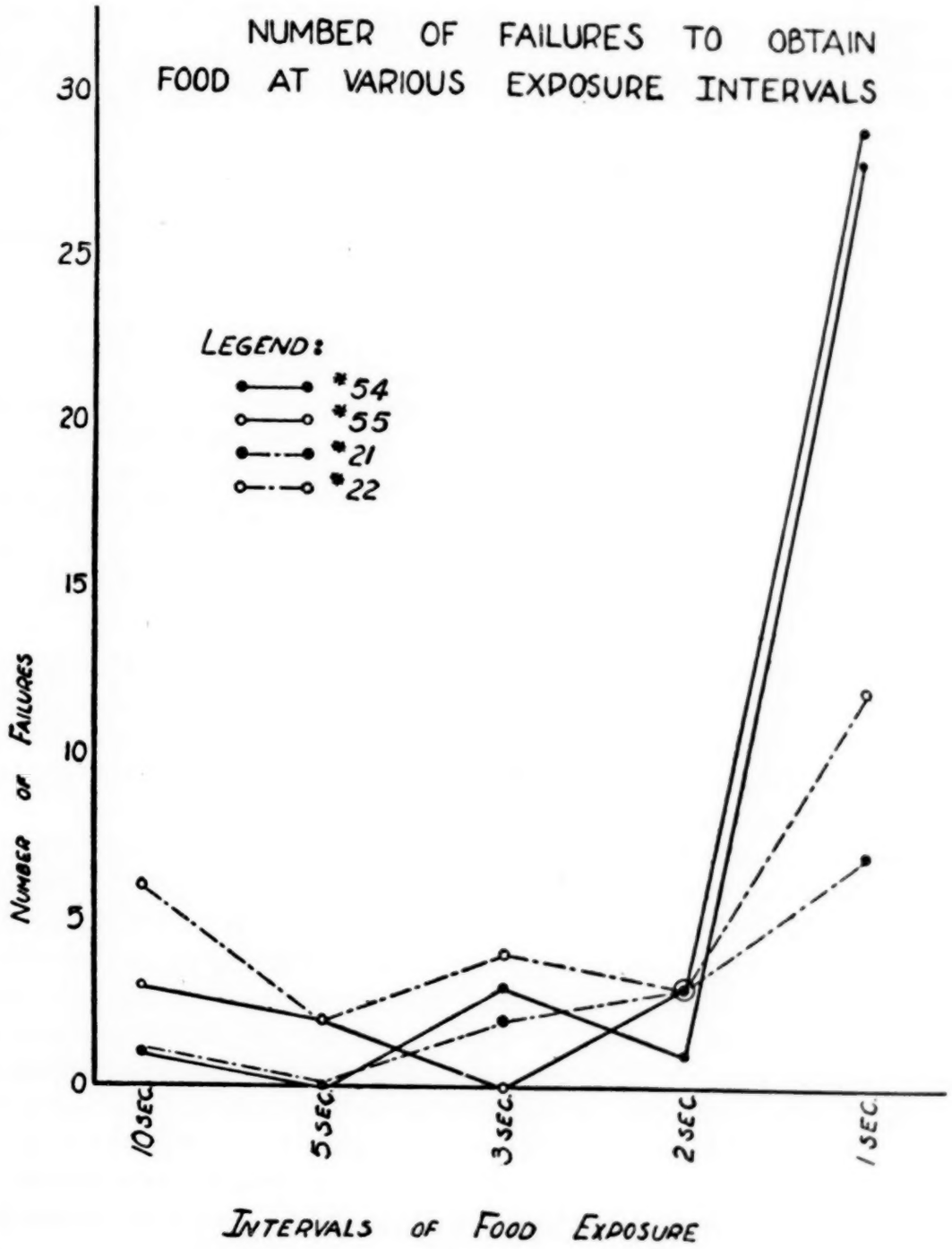

FIG. 1

22, who required 75 trials to attain the criterion of 90 percent correct responses in 50 consecutive trials.

No reliable differences between the normal and the operated subjects exist save at the one-sec. food exposure interval. The *t*-value

for the difference between the operated and the intact animals at this exposure interval is 18, and this difference is significant at the one percent confidence level with two degrees of freedom.

Similar data were obtained in Test 6, in which all exposure intervals were presented in irregular order each day. No differences were obtained at any food exposure interval save for the one-sec. interval. Subjects 21, 22, 54, and 55 made 3, 5, 7, and 9 errors respectively; *i.e.*, the operated monkeys made twice as many errors as the normal animals at this exposure interval.

The number of errors made following the various inter-trial intervals by the normal and operated subjects is given in Table I. These

TABLE I

TOTAL NUMBER OF ERRORS MADE BY OPERATED AND UNOPERATED MONKEYS FOLLOWING THE 6 INTER-TRIAL INTERVALS

Animals	Inter-trial Interval					
	10 sec.	12 sec.	14 sec.	16 sec.	18 sec.	20 sec.
Operated	27	20	19	12	14	14
Intact	14	12	11	8	7	4

data show that more errors were made by both operated and non-operated subjects at the shorter inter-trial intervals. However, the ratio of the differences between the operated and intact monkeys was at least as great at the longer inter-trial intervals as it was at the shorter inter-trial intervals.

The errors made by all animals were tabulated in terms of errors made on reversal and non-reversal trials. A reversal trial is defined as one in which the particular food platform correct was incorrect on the previous trial. A non-reversal trial is defined as one in which the particular food platform correct was also correct on the previous trial. The normal animals, 21 and 22, made 53 and 59 percent of their errors on the position-reversal trials, and the operated animals, 54 and 55, made 40 and 54 percent of their errors on the reversal trials. These differences are not significant. Certainly there is no tendency for the operated animals to make a greater percentage of errors on the position-reversal trials than did the normal monkeys. Thus the inferior performance of the operated subjects appeared, consistently, to be a failure to initiate their responses with sufficient rapidity at the one-sec. exposure interval, but the shifting from side to side demanded by the reversal trials did not produce any additional decrement in the prefrontal animals.

VI. Discussion

Observation of prefrontal monkeys suggested to the authors that these subjects seemed less able than intact monkeys to 'shift their orientation' selectively in a situation demanding frequent alternation of two responses. The test described in this paper was designed originally to see if such a difference could be objectively demonstrated between normal monkeys and monkeys with large frontal lesions. It was thought that the reversal trials might prove to be particularly indicative of such a loss.

Differences between the operated and non-operated subjects were obtained. The results, however, differed markedly from those expected on the basis of the tentative hypotheses which the experiment was designed to test. No significant differences were obtained between the reversal and the non-reversal trials. Shifting of response from right to left, or left to right, did not produce a greater decrement in operated than in normal monkeys in this simple test. This precluded any explanation in terms of shift of orientation.

No statistically significant loss appeared save at the one-sec. exposure interval. Observation of the subjects indicated that errors were frequently made even though the prefrontal animals were oriented toward the correct food platform. Such observations suggested that differences between normal and operated monkeys were better described as a failure to 'initiate behavior' than as a failure of 'orientation.' This failure to initiate behavior at the short exposure interval is particularly striking, since the animals were thoroughly familiar with the test situation and responded effectively and consistently at the longer exposure intervals. The design of the experiment, however, does not permit any detailed analysis of the nature of the process which accounts for the difference between the normal and operated subjects.

The data of this paper do show that bilateral destruction of the prefrontal areas may produce in the monkey a deficit in response to a simple problem which does not involve the formation of any new association or the utilization of any principle or symbolic process. The possibility that the simpler defect or defects may be in part responsible for deficit appearing in more complicated tasks cannot be ignored.

VII. Summary and Conclusions

(1) Two rhesus monkeys following bilateral removal of the prefrontal areas and two intact rhesus monkeys were tested on a test of 'initiation of behavior.' This problem required only that the subject remove food from one of two metal plates in a limited time interval.

(2) The operated animals made significantly poorer scores than the normal animals on those trials in which food was exposed on the food platform for a single second. This difference did not result from lack of familiarity with the problem, as indicated by the fact that significant difference did not appear at the longer exposure intervals. No significant difference was found between normal and operated subjects in the percentage of errors made on the reversal as compared with the non-reversal trials at any exposure intervals.

(3) These data show that bilateral removal of the prefrontal areas in monkeys may produce loss in a simple problem not involving the formation of new associations or the utilization of any symbolic process.

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SOME COMPLICATIONS OF ASSOCIATIVE PROCESSES

BY E. L. THORNDIKE

The experiment deals with paired associates in which the first members of the pairs included many words classified in one way, and the second members of the pairs included many words, also classified, but in a very different way. Our interest is almost entirely in the wrong responses in the memory test. These reveal features of associative processes which are not obvious in the classical experiments with memory and free association.

PROCEDURE

The 112 pairs of words shown in Table I were read to the subjects six times, always in a scrambled order, and using four different orders.[1]

The first members of these 112 pairs include twelve sets of words of closely similar sound within each set as follows: bail jail kale nail pail tail trail wail; bake cake fake hake quake sake; blame came dame fame flame game lame shame tame; beet bleat cheat cleat heat neat seat sleet; bike dike like Mike spike strike tyke; blend end fend lend mend send tend vend; bin din fin in kin Lynn pin Quinn shin spin thin whin; crow doe foe go Joe show toe throw woe; book brook hook rook took; fond pond wand; fonder ponder yonder; fish wish. They also included 32 words which did not rhyme *inter se* or with the 80 listed above.

The second members included 15 sets of words similar or closely related in meaning as follows: one two six nine; forty-seven fifty-three sixty-two seventy-eight; green magenta purple yellow; aspirin fever quinine pill; Egypt Germany Holland Rumania; Kenneth Peter Robert William; Alice Joan Lulu Winifred; butter cake ice-cream muffin; anxiety dread honor remorse; gladness glee happiness joy; affluent prosperous rich wealthy; foot inch kilometer yard; devil heaven pray worship; daisy rose tulip violet; courtship hug kiss love.

The second members also included the following: he him she her they them we us it and but or so as by of than the rough smooth always never gentle harsh simple complex.

The remaining 25 words were miscellaneous and *night* occurred twice. The subjects of the experiment were told nothing of all this, but merely: "I shall read pairs of words, like *now—robber, speak—vain, local—temperature*. You will listen to what I read. Those on the north side of the room will listen attentively and try to remember what they hear. Those on the south side of the room will listen just enough to be able to say that they kept awake and heard what I said."[2]

As soon as the sixth reading was finished each subject was tested with the two sets, each of 28 words, shown below, being asked to write the word that followed each in the reading if he remembered it, and if he did not to write whatever word came to his mind. For convenience the word that followed it in the reading will be called the "right" response and all other words "wrong" responses. The percentage of "right" responses is given after each word.

First half of test: animal 41, bake 21, bit 10, blend 7, brook 2, came 0, cleat 31, dike 48, fake 23, flame 2, fond 3, good 84, in 31, kale 2, last 72, like 7, long 18, Lynn 2, manual 28, nail 10, neat 10, rook 25, shame 8, spin 2, ten 75, toe 7, vertical 97, woe 10.

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[1] The order in the fifth reading was the same as in the third. That in the sixth reading was the same as in the second.

[2] Records were kept separately for the two halves of the group, but in all that follows they will be combined since all the conclusions to be presented hold true for both groups.

TABLE I

animal	slayer	for	them	sake	Joan
arrive	depart	game	one	seat	her
as	ever	go	nine	send	devil
bail	two	good	bad	shame	inch
bake	slice	hake	kiss	shin	complex
beet	gladness	heat	rose	show	sixty-two
better	than	high	low	sleet	anxiety
bike	they	hook	violet	spike	Germany
bin	heaven	hot	as	spin	daisy
bit	harsh	human	nature	strange	attitude
blame	Kenneth	if	celebrated	strike	glee
bleat	smooth	in	the	strong	weak
blend	him	jail	forty-seven	such	sweet
book	quinine	Joe	it	tail	Peter
brave	Philip	kale	he	tame	joy
brook	pray	kin	muffin	telephone	call
cake*	prosperous	lame	magenta	ten	cents
came	butter	last	night	tend	horror
cheat	Winifred	lend	cake*	thin	we
cleat	Egypt	like	always	throw	yard
crow	so	long	litany	tyke	affluent
daily	bread	Lynn	pill	toe	William
dame	rough	manual	of	tomorrow	morning
day	night	mend	fifty-three	took	Rumania
dike	yellow	Mike	fever	trail	gentle
din	kilometer	nail	remorse	twenty	disciples
doe	us	neat	six	vend	aspirin
end	green	next	adverb	vertical	horizontal
express	declaration	old	friends	wail	worship
fake	happiness	pail	rich*	wand	tulip
fame	Lulu	pin	never	whin	hug
fend	foot	pond	courtship	wish	but
fin	purple	ponder	dread	with	many
fish	she	quake	or	woe	seventy-eight
flame	and	Quinn	simple	written	by
foe	ice-cream	rich*	poor	yonder	Robert
fond	wealthy	rook	love	yours	mine
fonder	Holland				

* *Cake* and *rich* occurred both as first members and as second members.

Second half of test: arrive 52, as 31, bike 7, bin 7, bleat 3, book 5, crow 30, day 74, fend 0, fish 28, for 18, game 18, hake 2, heat 7, jail 59, lame 13, lend 3, next 21, pail 10, Quinn 2, sake 0, sleet 2, strange 16, tame 3, tomorrow 64, took 36, written 20, yonder 30.[3]

Results and Discussion

Complications by Temporary Mental Set

If these 56 words had been presented as a free association test without the preceding readings of the 112, there would have been only a few responses by rhymes except for *bake-cake* where a frequent sequent or associate of the first member also rhymes with it. The six readings of the 80 words in the rhyming sets of two to twelve words flood the mind with *āl*, *ām*, *āk*, *īk*, *end*, etc., rhymes, and cause a subject to give many rhymes as responses when he does not remember the correct response. For example nearly seven percent of the wrong responses to *jail*, *kale*, *nail*, *pail*, *bake*, *fake*, *hake*, *sake*,

[3] *Robber*, *robbin*, and *robin* were called "right." The use of *robber* in the instructions apparently caused Robert in the reading to be misperceived.

flame, *game*, *shame*, *tame*, *bike*, *dike*, *like*, *bin*, *in*, *Lynn*, *Quinn*, and *spin* are rhymes, not counting *bake-cake*. This is in spite of the fact that only one of the 112 pairs (*crow-so*) had a second member that rhymed with its first member, and only five of the 112 second members, including *cake*, rhymed with any word whatsoever among the 112 first members. The readings would in reason set the mind strongly against connecting any first member except *crow* with a rhyme as sequent, and persons ambitious to show competence in memory, as most of the subjects probably were, would in reason avoid thinking of rhymes in the test more than they would do in a free association experiment.

The brain is thus no more reasonable in its temporary sets than in its one-to-one connections. The readings of the paired words predispose it to think of rhymes, but not to control its thoughts by the thoughts that rhymes of any sort were almost exclusively within the first members, and that *crow-so* was the only rhyming pair among the 112. If the 58 words of the test had been given without any readings of the 112 pairs, the instructions being to "write after each word whatever word comes to your mind," a very large percentage of the responses to a word would have been words which had been frequent sequents of the word in speech and writing, as in *bake-bread* and *bake-cake*, or words which come to mind when one thinks what the word means, as in *bake-cook*, *bake-stove*. Among the latter, synonyms, opposites, and the names of things commonly associated with the thing named by the word would be frequent.

In the wrong responses of the experiment such frequent or fit associates of the word are very much rarer.

Among 968 wrong responses to the words in *ām*, *āk*, *āl*, *īk* and *in* in the test, 365 had apparently neither any appreciable frequency as sequents or associates nor any fitness as interpreters for the stimulus words in question. This is about seven times the corresponding figure for the Woodrow-Lowell (**1**) records from children and the O'Connor (**2**) records from adults. Of these 365, 98 were words occurring as second members of the pairs read, and consequently had some slight suitability as attempts to guess the right response. Of the 365, 55 were words occurring as first members of the pairs read and, with the exceptions of *cake* and *rich*, were utterly unsuitable as guesses at the right response. They had, however, been heard six times each during the hour preceding the test. Being in mind they came out in the test, irrationally. Of the 365, 212 were words not heard among the 224 of the experiment. Two features of the mind's temporary set permit this efflux of words which free association would not have permitted. The first is the repeated reading of 112 pairs in 80 of which the second member had little or no connection with

the first by frequency, fitness, or any other force, these being the result of random pairing of words in *ām*, *āl*, *āk*, *end*, etc., with names of 8 numbers, 4 colors, 4 nations, etc. This puts a person more or less in a frame of mind and brain to tolerate, perhaps even to welcome, unheard-of and meaningless pairs. The second is the familiarization with the first members by hearing each six times, and each time presumably thinking of what the word means. The tendency to pursue the sound-meaning connections further, as by synonyms and opposites of the word, or activities, uses, adjuncts, and concomitants of the thing it names, is thereby weakened. Among the 634 responses by words not among the 224 read, only 30 were synonymous with the stimulus word, only 30 were opposites of it, and only 116 were frequent associates of it—these by very generous classification into these groups. Rhymes were more frequent than synonyms or opposites.

It is somewhat of a mystery why the set of mind induced by the instructions and the six hearings of the 112 pairs should not cause a considerable number of responses by the words *words*, *rhyme* or *rhymes*, some responses by *names*, *numbers*, and *pronouns*, and some responses by *psychology*, *experiment*, or *memory*. In a total of about 1500 wrong responses by words not in the 224 read their occurrences numbered as follows: None of *names*, but 5 of *name*, 2 as responses to *Quinn*, 1 to *Lynn*, 1 to *came*, and 1 to *shame*. None of *words*, but 7 of *word*, 1 as response to *bin*, 1 as response to *next* and 5 as responses to *written*. 1 of *psychology*, as a response to *book*.

Psychology to *book* and *word* to *bin* are the only responses of these that can be adduced as evidence that the words written were influenced by knowledge of the prominent features of the words used in the experiment, or of its general nature. The evidence is extremely weak because both of these cases are better explained otherwise. The rhymes had, as has been shown, a great influence upon the connections made, but they did not cause anybody to write *rhyme* as a response to any word. The words *jail* and *woe* were responded to by some 'wrong' number 11 and 12 times respectively, but never by *number*, though we have *jail-more*, *jail-tulip*, *woe-din*, *woe-good*, *woe-Kenneth*, *woe-longer*, *woe-Nelly*, and *woe-sleep*, as proof that a very slight pressure toward *number* could have evoked it.

The facts become somewhat less mysterious if we consider that the mind is more a multitude of connections than a storehouse, and is not classificatory or logical except when the forces of repetition and reward make it so.

The Influence of Similarities in Sound Among First Members

In the test there were 6 *ām* words, 4 *āl* words, 4 *āk*, 5 *ēt*, 3 *end*, 3 *īk*, 5 *in*, 3 *ō*, and 4 *ook*.

There were 135 erroneous responses to these 37 words by the 37 words that had been their sequents in the readings. Those which had been the sequents of a word of similar sound were as follows, the word of similar sound being given in italics: 1 of kale *pail* rich, 1 of nail *jail* forty-seven, 2 of hake *bake* Alice, 1 of sake *bake* Alice, 1 of bleat *cleat* Egypt, 1 of neat *heat* rose, 1 of fend *blend* him, 2 of lend *blend* him, 2 of blend *fend* foot, 3 of like *bike* they, 1 of Lynn *Quinn* simple, 1 of bin *in* the, 3 of woe *crow* so, 2 of brook *took* Rumania, 1 of rook *took* Rumania. Only 9 of these 23 have an appreciable probability of occurrence by direct connections, namely: *kale-rich* (with a rare slang meaning of *kale*) *lend-him*, *like-they*, *woe-so*.

With these 23 we may compare the 112 wrong responses by words from the 37 which had not been the sequents of a word of similar sound. They are only half as frequent in proportion to the opportunities for them as are the 23 which had been the sequents of a word of similar sound, and the percentage of them that would have no appreciable probability of occurrence by direct connections in a free association test is not as high as in the 23 (51 for them and 61 for the 23). The likeliest explanation of this greater frequency in proportion to opportunity is that in the six readings connections (of little strength, however) were formed between the *ām* sound and all the sequents of *blame*, *came*, etc., between the *āl* sound and all the sequents of *jail*, *kale*, etc., between the *āk* sound and all the sequents of *bake*, *fake*, etc., and so on.

An alternative or accessory explanation, by the action of unconscious cerebration, would be somewhat as follows: A stimulus word may evoke a word and this word may evoke a third word which may for one or another reason be reported by the subject as his response to the stimulus word. One such reason could be that the second of the three words was swamped and driven out of mind by the third, so that the subject could not remember what it was or even that he had thought of it. As an extreme case, some physiological event corresponding more or less to the thought of the second word might occur and lead on to the physiological event corresponding to the thought of the third word without any thought whatsoever of the second word. *Nail* would evoke *forty-seven* via *jail*. *Hake* would evoke *Alice* via *bake*.

The Influence of Similarities in Meaning in Second Members

The influence of similarities in meaning among second members seems to be nil. Among the second members of the 112 pairs were 72 forming 18 groups of four similar words such as *one*, *two*, *six*, *nine*, or *magenta*, *green*, *yellow*, *purple*, or *Kenneth*, *William*, *Peter*, *Robert*. In the test *two* is no commoner as a 'wrong' response to the first

terms that had *one*, *six* or *nine* as a sequent in the training than as a wrong response to any other first terms; *green* is no commoner as a wrong response to a first term which had *magenta*, or *yellow* or *purple* as a sequent than as a wrong response to any other first term; and similarly for the rest of the 18 groups. The 36 relevant words in the test had from the 61 subjects 257 'wrong' responses from the list of 72 second-member words in the 18 groups. Of the 257 only 8 were from words in the group of four of similar meaning that included the 'right' response. If we count all the 8 numbers as similar, all the names both of boys and of girls as similar, all the 8 emotions as similar, and all the 8 pronouns as similar, we have 17 and 248 in place of 8 and 257. There is no support for the doctrine that a situation tends to evoke a response which is similar (in meaning, function, class or topic) to the response which has been made to the situation in question.

The Influence of Connections with the General Condition of Being Awake and Desirous of Saying or Writing a Word

Skinner (3) has shown that persons urged to hear indifferent faint sound-sequences as words, phrases or sentences, hear mainly words which have been very frequent in their experience. This fact supports the assumption that repetition strengthens connections that lead from the general condition of being awake and desirous of saying or writing a word as well as from the more specific parts of the situation. According to this assumption, the words written in our test that had no demonstrable connections with the words of the experiment should include a surplus of words often used by the subjects. They do. In fact 63 percent of them are AA words of the Thorndike-Lorge counts (4), that is, are among the 1066 words occurring 100 or more times per million running words. This means a probable surplus of over 50 percent for these very common words since the average 'active' vocabulary of the 61 subjects of the experiment was probably well above 8000.[4]

(Manuscript received April 13, 1943)

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[4] I use *active vocabulary* to include the words used by a subject in speaking, writing, and thinking.

THE EFFECTS OF AVITAMINOSIS-A ON VISUAL INTENSITY DIFFERENCE THRESHOLDS IN THE RAT[1]

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I

Introduction

In previous studies the effect of avitaminosis-A on visual absolute intensity thresholds has been extensively investigated. The present report is concerned with the effect of vitamin A deprivation on visual intensity difference thresholds. That the intensity discrimination capacity of animals deficient in vitamin A may not remain stable is indicated by previous work concerning the effect of avitaminosis-A on the dark adaptation process (**1**, **5**, **8**, **9**).

The present experiment was set up to measure just perceptible visual intensity differences for the rat and to observe the effects of dietary avitaminosis-A on these difference thresholds. It was found that, under this dietary deficiency, there is an increase in the visual intensity discrimination thresholds.

II

History

The prediction that avitaminosis-A would cause an increase in visual intensity discrimination thresholds was based upon an extensive series of converging evidence. Previous experimentation has indicated that vitamin A is a necessary element in the chemical events constituting the visual cycle and that man and other mammals deprived of this element exhibit a rise in visual absolute intensity thresholds.

In 1925 Fredericia and Holm (**1**) and Holm (**5**) discovered that the regeneration of visual purple following light adaptation was much delayed in rats deprived of vitamin A as compared with control

[1] The authors wish to acknowledge the financial assistance of the University of Nebraska Research Council.

animals receiving an adequate diet. This finding was later substantiated by Tansley (**10**). More recently Morgan (**8**), using the method of absolute thresholds, with rats as subjects, concluded that the rate of recovery of visual sensitivity after light adaptation is much retarded in avitaminized animals and, furthermore, that upon return to the normal diet after prolonged deficiency, normal acuity in visual sensitivity is never reached due to some physiological or anatomical alteration.

Night blindness of the same variety as that found in the laboratory rat has been produced experimentally in human beings by a vitamin-A-deficient diet. Reports by several observers (**2, 3, 4, 6, 12, 13**) have shown that a steady rise of visual absolute intensity thresholds follows the removal of vitamin A from the diet. This rise continues for as long as the deprivation is maintained. On return to a diet adequate in vitamin A (**3, 4**) or on injection of vitamin A (**12**) there results a decrease in the threshold eventually approaching complete recovery.

The role of vitamin A in the photochemical processes of vision has been demonstrated. Wald (**11**) has described this photochemical system on the basis of experimental results as a cycle wherein vitamin A appears as a precursor of visual purple (the photosensitive substance) as well as the product of its decomposition. Thus the results of behavior studies are corroborated by biochemical analyses.

In view of the functional relationship between visual absolute intensity thresholds and visual intensity difference thresholds, and in consideration of the converging evidence cited above, the prediction was made that avitaminosis-A would cause an increase in visual intensity difference thresholds. The further prediction was made that, after the thresholds had increased, recovery would result when the animal subjects were returned to a diet adequate in vitamin A.

III

Apparatus and Procedure

The apparatus used in this experiment was developed at the University of Nebraska (**9, 13, 14**). It consisted of a modification of the apparatus employed by Lashley (**7**) for the analysis of pattern vision in rats, combined with two long light-chambers placed directly behind the jumping platform. The animal subject was required to run up a wire-mesh ladder in order to reach the top of the jumping-platform [3] at which point it was required to choose and enter one of two individual light-chambers which extended 12 in. back and joined the long light-chambers. A milk-glass plate, $\frac{1}{8}$ in. thick, separated each compartment from its light-chamber and at the back of each compartment was a food cup into which equal amounts of food were placed. The light sources were two 60-watt daylight lamps mounted on movable transports and were con-

[3] The platform and the ladder were replaced later by a metal-grilled platform which was so connected that an electrical shock of regulated intensity could be given the animal by the experimenter.

tained in the two long alleys. The light was projected along each alley and transmitted through the milk-glass panels to be seen from the jumping-platform.

The lamps were equated for intensity by comparison with standard lamps on an optical bench. By means of a system of pulleys in the light chambers the lamps could be moved equal distances but in opposite directions. The distances moved from a zero point were measured in terms of units, two in. in length. A pointer and scale on the outside of the light-chambers indicated the number of units, or distance, from the zero point. This figure was then doubled in order to obtain the number of units between the two light sources. Thus, at the zero point $I_1 = I_2$ ('I' indicating the intensity and the subscript denoting the alley) as measured from the platform. When the lamp in alley 1 was moved three units forward, the lamp in alley 2 was moved three units backward and the difference in their intensities was six units, or $(I_1 : +3)$ and $(I_2 : -3)$. Brightness differences of the two panels in terms of apparent foot-candles were obtained by measurement with a Macbeth illuminometer. The pointer of the apparatus scale was set at the various scale units and the brightness of the panel was obtained in terms of apparent foot-candles by comparing it with the standard lamp of the illuminometer. Thus, any increase in the brightness difference threshold of an animal could be converted from units on the apparatus to apparent foot-candles.

As in the color vision experiments previously carried out in this apparatus (**9**, **14**), precautions were taken to eliminate the possibility of secondary cues and to require the animals to learn the discrimination on the basis of the intensity difference only. The apparatus was painted lamp black; there was no light leakage and the light-chambers were uniform in every respect. The experimental room was very dimly illuminated and the apparatus was shaded from the rest of the room by means of curtains.

The animals used were kept in shaded cages and were further dark adapted for a period of approximately 30 min. before each daily experimental series of trials. They were taught to climb the wire-mesh ladder and to go toward the brighter (or darker) of the two milk-glass plates. If the animal made a correct choice, it was allowed to eat a small pellet of vitamin-A-free food from a food dish at the back of the compartment. However, if the choice was incorrect, the floor of the compartment swung downward and the animal fell into a net below and received no reward. In either case the animal was retrieved quickly and placed on the ladder for the next trial.

When the animals had learned to respond positively to the lighter (or darker) compartment, the intensity difference was decreased until the difference threshold was determined. This point was indicated by a decrease in the accuracy of response from 100 percent to approximately 50 percent. The difference threshold was always determined by a diminishing series of intensity changes, since in this way the animal made fewer errors and consequently was punished less frequently than would have been the case had the procedure been reversed. After the threshold had been determined, a just supra-liminal difference was maintained until further change was necessitated by an increase in the percentage of errors, the latter being indicative of a rise in the animal's threshold.

Five young hooded rats completed the experiment.[3] From the time of weaning they had been fed on a diet depleted of vitamin A but adequate in all other respects. The animals were handled for several days prior to being placed on the apparatus in order that they might become accustomed to the experimenter and the experimental situation. When first placed upon the apparatus they were allowed to wander freely and to find food in either cup. Both stimulus panels were of equal brightness at this time and both chamber doors were locked.

After five to seven days of this preliminary training the experimental procedure was started. The animal was trained to go to the brighter (or darker) panel. The brighter panel occurred on the right or left in random order but appeared on each side in 50 percent of the total number of trials. The discrimination habit was established within 10 to 16 days. Thirty trials per day were given each animal except for the first few days when only half this number were administered. An average of 300 trials were necessary for mastery to the point of 90 percent accuracy. When the percentage of correct responses for each animal reached or passed 90 percent the brightness difference between the two panels was gradually decreased until the threshold for each

[3] Additional animals were started but were unable to finish the experiment due to the effects of avitaminosis-A. The difficulty in keeping animals alive for extended periods under the conditions of this experiment has been noted by previous experimenters.

animal was reached. This point was checked over a period of days and the intensity difference was maintained until a change to a new point was made necessary by a rise in the animal's threshold. Thus, a brightness difference was always maintained such that the accuracy of response was just above that to be expected by chance alone.

IV

Results and Conclusions

Table I presents the rise in visual intensity difference thresholds for the five animals surviving the experiment. Threshold changes

TABLE I

Rise of Difference Thresholds

Day of Experimental Period	Threshold Difference (Apparent Foot-Candles)
Animal 1	
1–56	0.58
57	0.73
63	1.09
68	1.44
73	1.60
Animal 2	
1–51	0.58
52	0.73
53	1.44
54	1.60
55	1.76
Animal 3	
1–60	0.58
61	0.73
62	1.09
63	1.44
64	1.60
Animal 4	
1–50	0.58
51	0.73
52	1.44
53	1.60
54	1.76
59	1.92
60	2.07
(Normal Diet)	
61	1.76
63	1.60
64	1.44
65	1.09
66	0.73
Animal 5	
1–51	0.58
52	0.73
54	1.44
55	1.60
56	1.76
57	1.92
61	2.07
(Normal Diet)	
62	1.76
64	1.60
65	1.09
66	0.58

are given in terms of apparent foot-candles. It will be noted that as the period of time on a diet deficient in vitamin A increased the difference in the intensity of the stimuli necessary to be discriminated as different also increased. This increase amounted to from three to four times the original intensity difference before the conclusion of the experiment.[4]

It will be noted also that, when two of the animals were returned to a normal diet containing cod-liver oil, there resulted a decrease in their difference thresholds. Original thresholds were approximated after four or five days of adequate diet.

[4] The experiment was concluded when the animal became too weak to perform on the apparatus. The animal was then returned to a normal diet.

These facts substantiate the predictions made at the beginning of the experiment. Avitaminosis-A causes an increase in visual intensity difference thresholds. The increased thresholds may be returned to normal by inclusion of vitamin A in the diet. The recovery period is much shorter in duration than the period necessary for the first appearance of an increased threshold, *i.e.*, four or five days as compared to 50 to 60 days. These results add further evidence for the importance of vitamin A in the visual cycle.

V

Summary

In previous studies the effect of avitaminosis-A on absolute intensity thresholds has been extensively investigated. The present report is concerned with the effect of vitamin A deprivation on intensity difference thresholds.

A discrimination habit was established on a modification of the Lashley discrimination apparatus and required an average of 300 trials for mastery to the point of 90 percent accuracy. The rats, from the time of weaning, had been fed on a diet depleted of vitamin A but adequate in all other respects. After establishment of the habit the intensity difference threshold for each animal was determined.

As the length of time on vitamin-A-free diet increased it became necessary to increase the intensity difference in order to maintain a threshold response. The difference limen of the animals increased from three to four times the original before the experiment was discontinued.

Two of the rats were returned to a normal diet after their difference thresholds had increased significantly. There followed immediately a decrease in difference thresholds, the original thresholds being approximated in four or five days.

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THE CURVE OF RETENTION FOR SUBSTANCE MATERIAL

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The principal problem of this investigation was to determine the form of the curve of forgetting for substance material. Secondary problems were to investigate the effect of length of interval upon variability of recall, the percentage of cases exhibiting reminiscence, and sex differences. Our interest in this question was occasioned by the difference in the curves of retention for verbatim and substance items found by English, Welborn, and Killian (4). It will be recalled that their curve for the verbatim items had the usual Ebbinghaus form, showing increasing loss with increasing length of interval, but the curve for substance items had an opposite form, *i.e.*, showed an increase in amount remembered with increase in length of interval up to a certain time, and then a slight decrease. In one experiment the amount retained of substance items was greater after 71 days than after one day. This is so different from both the ordinary course of experience and from other experiments on retention that we thought it worth while to reinvestigate the curve form for the retention of substance items.

Procedure

For materials we used a modified form of Van Wagenen's *Reading Scales in Educational Psychology* (5). The test was shortened by including only the first 12 paragraphs, and some of the questions were changed so as to conform more closely to the requirements of our experiments. The questions relating to the content of a paragraph were placed immediately below it. All had the true-false form, and were 50 in number. Particular care was taken to make the substance items distinguishable from verbatim items. The criterion used for a substance item was one recommended by English, namely, that it should never be capable of being answered on the basis of a single sentence in the text. A total of 95 college students taken from four classes in elementary psychology and one in English composition were used as subjects. In using psychology students there was a possibility that the text material and the course of study might cover some of the same points. To guard against this, we used two precautions. First, we had the psychology teachers check the content of the test and assure us that the items were not covered in their beginning course; and second, we used a class of English composition students as a control group.

The procedure used was to give each student a copy of the test and ask him to read it and mark the questions true or false according to his interpretation of the reading. He was allowed to reread as much as he wished. There was no time limit, but all students finished within the class period of 50 minutes. In the re-test, the same questions were given, but without the accompanying reading matter. The intervals used were zero, 1 week, 4 weeks, 8 weeks, and 12 weeks. All subjects took the immediate test, but for the re-test they were divided into five

groups, each of which took the re-test only once, according to a schedule. Two groups, one control and one experimental, took the re-test after an interval of 12 weeks.

The reliability of the test was measured by the split half method from the results of the immediate test. The resulting correlation was .575, which was increased to .73 by the Spearman-Brown formula.

Results and Discussion

Table 1 and Fig. 1 give the principal results. The number of subjects used in this table was reduced from 95 to 89 because of the absentees in the re-test. Only those who were present for both tests were used in the calculations given in the table. In addition to

TABLE 1

Average, Immediate, and Delayed Recall Scores for All Groups

Group	Number of Subjects	Interval	Immediate Recall			Delayed Recall		
			Raw	S.D.	Percent	Raw	S.D.	Percent
A	17	1 week	35.90	5.34	71.80	34.29	4.17	68.50
B	17	4 weeks	35.82	3.73	71.64	31.71	4.54	63.42
C	12	8 weeks	35.08	5.87	70.60	30.58	4.19	61.16
D	24	12 weeks	35.92	4.95	71.84	30.75	2.63	61.50
E (control)	19	12 weeks	34.42	8.22	68.84	31.21	4.83	62.42

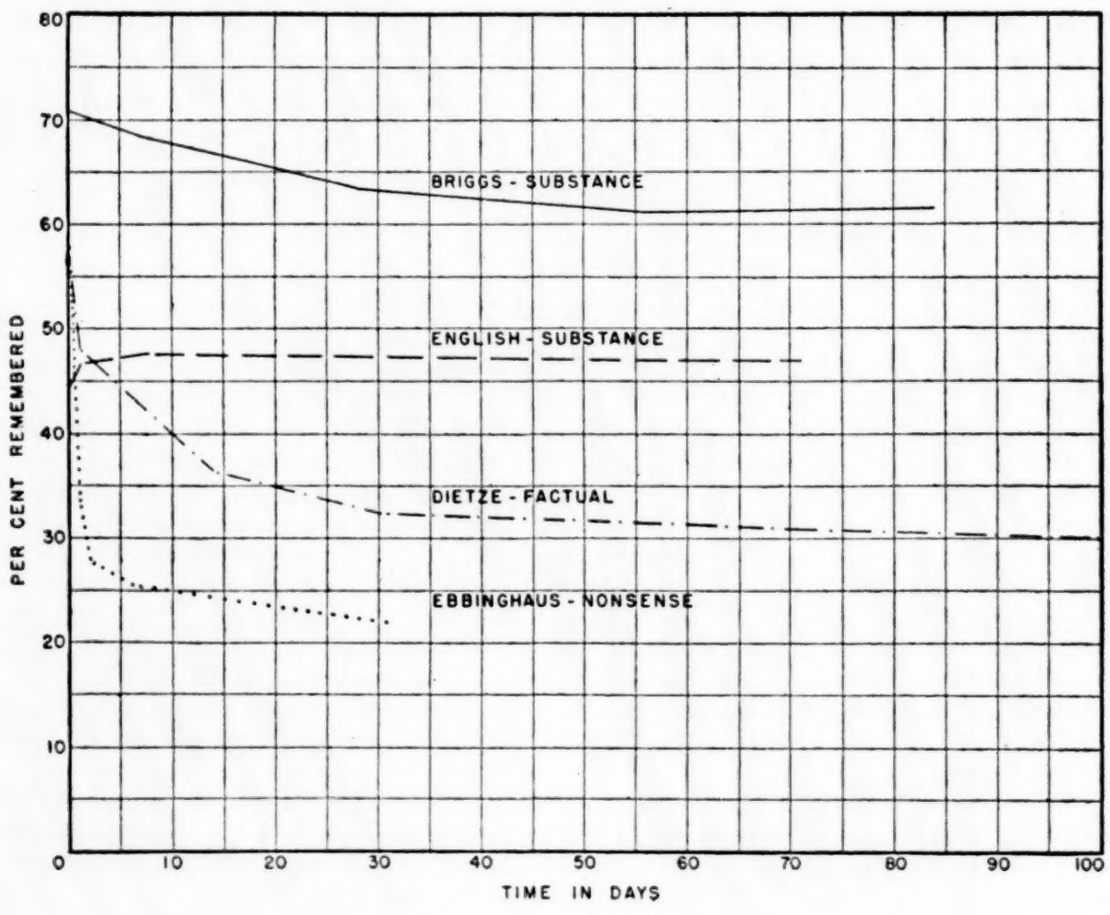

Fig. 1. Curves of retention.

giving the curve for our own data, Fig. 1 gives the curves for the results obtained by Dietze and Jones (2), English, Welborn, and Killian (4), and Ebbinghaus (3). Except for amount and rate of retention, our curve has the usual form, that is, it shows decreasing amount of retention in relation to length of interval, and like the usual type, it shows that the retention decreases at a decelerating rate. Unlike the English-Welborn-Killian curve it does not show reminiscence or a higher retention after 30 or 71 days than after one day. We suspect that the rising curves found by English and his co-workers are due to the special conditions of their experiment, among which are inhibition and relearning. The new phraseology of the tests in which the ideas of the text were cast at first may have inhibited their recognition. The inhibition was at its maximum in the test after ten minutes, had spent most of its force after one day, and then disappeared, permitting the recognition of old ideas. The fact that the same subjects took on same test three or four times permitted relearning and strengthening through repetition. The rise in the curve may be a function of the gradual disappearance of inhibition, and its maintenance after reaching the peak may be a function of repetition. In our experiment the effect of repetition was reduced to a minimum by restricting the subjects to one retest, and the inhibition from new phraseology was reduced to a minimum (1) by allowing the subject to reread the text after he saw its questions in the first test, and (2) by making the intervals long enough to allow interference to disappear. These hypotheses make it unnecessary to assume that recall of substance items is an entirely different process from the recall of verbatim items. The differences in the retention of substance, factual, and nonsense items may be thought of as a function of at least two factors: the stability of the organization inherent in each type of material and the measure of retention. Because of their rich connections, meaningful ideas would have a very stable organization and a high resistance to the disturbance of subsequent unrelated experiences. Factual material being more isolated would have a lower degree of stability, and nonsense material would be the least stable of all, and consequently, the most rapidly eradicated. That the method of measure used is a factor may also be inferred from Luh's experiment which showed that the relearning or saving method, the one used by Ebbinghaus, yields a much lower degree of retention than the recognition method, a form of which was used for obtaining the other curves in Fig. 1.

Although reminiscence does not appear in our curve, which is based on group averages, it is still possible that it conceals reminiscence appearing in a minority of individuals. A search for reminiscence in individual cases showed this effect to be present after

1 week in 29.2 percent of the cases, after 4 weeks in 17.6 percent of the cases, after 8 weeks in 25 percent of the cases, and after 12 weeks in 12.5 percent of the cases. Again these findings disagree with those of English, not only in amount, but also in the direction of the change. In one study he found the percent of cases increased up to 69 at the end of 30 days. No such trend is present in our results.

That the variability of a group in retention has a trend towards decrease as length of interval after learning increases is shown in the decrease of the S.D. of the raw score from 5.34 to 4.17 after one week for Group A, and from 4.95 to 2.65 after 12 weeks for Group D. The corresponding variability scores show a decrease from 14.87 to 12.16 after one week, and from 14.18 to 8.55 after twelve weeks. Group D, however, shows an opposite trend for the four-week interval. The general trend of our results is confirmed by Dietze, who in four of his groups found a decline in the S.D. of the retention scores from the immediate interval to the 100-day interval, but in three groups the S.D. increased. The change in variability appears, therefore, not to be consistent.

In regard to sex differences in retention for the material in question, our results showed no significant difference. On the average the girls were slightly superior. In the immediate test the girls made a mean score of 36.24 and the boys a score of 34.94. In the test after twelve weeks the girls made a mean score of 31.81 and the boys a mean score of 30.23. The critical ratio of the difference in each case was only 1.4.

Summary

The problem of this experiment was to investigate the form of the curve of retention for substance material or ideas, an idea being defined as a concept which cannot be derived from a single sentence in the text. Eighty-nine college students were tested for immediate comprehension of a rather difficult prose selection by 50 true-false questions. For the delayed retention test, the subjects were divided into five groups, each of which was tested for one of the following intervals: 1 week, 4 weeks, 8 weeks, and 12 weeks.

The curve of retention for substance material or ideas has the usual form: it falls at a decelerating rate. However, it has a much higher level than curves hitherto published for factual, nonsense, and substance material.

No confirmation was found for the rising curve of English, Welborn, and Killian. The reminiscence effect found in this curve is attributed to two factors: removal of inhibition from the new language in which the ideas were expressed and relearning from the giving of the same test to the same subjects three or four times.

A minority of the subjects showed reminiscence but its percentage, except in one case, declined with the length of the interval. Four of the five groups retested showed a decline in variability corresponding to the length of interval.

The girls were slightly superior to the boys in retention, but the differences were not significant.

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HEART RATE IN THE COMATOSE STATE OF AUDIOGENIC SEIZURES

BY F. L. MARCUSE AND A. U. MOORE

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Introduction.—In a preliminary investigation Marcuse and Moore (3) found a decrease in heart rate following audiogenic seizures. Subsequently Lindsley, Finger, *et al.* (1) reported results showing a decrease to 80 beats per minute from a norm of approximately 400. The purpose of the present experiment was to observe more systematically than in our previous study the extent to which heart rate decreased in the comatose state following audiogenic seizures.

Apparatus.—The heart rate was recorded by a Davis electroencephalograph; clip electrodes were attached ventrally and dorsally through the axis of the heart.

A miniature replica of the conventional Pavlovian frame was constructed for recording the heart rate of the adult rats. The animal was kept in the frame by means of two straps just behind the forelegs and in front of the hind legs. In the preliminary training of the rat these straps must be snug, but after a few days they may be loosened considerably so as to make sure that no artificial constriction occurs. The floor of the frame was movable and served a double purpose—it allowed for adjustment to the size of the animal, and it was of aid in the training procedure. In the first few days of training, if the animal struggles too much, it displaces the floor, and consequently is left suspended by the two straps—a situation which the rat soon avoids by ceasing to struggle.

A seizure cage of ¼-in. wire mesh, 7 × 7 × 10 in., was used. The cage was mounted on blocks of wood 2 in. high. In the area beneath the cage a bell was placed. The bell did not touch the floor of the cage and its hammer was approximately one in. below the cage. The bell was of the ordinary door-bell type activated by a transformer in an AC circuit.

Procedure.—In preliminary experiments the rat was kept in the Pavlovian frame and a bell, some 8–10 in. overhead, was used. It was found, however, that rats of known susceptibility had but few seizures in this situation where locomotion was restricted.[1] This method was given up, and the animal was placed in the usual seizure cage with the electrodes extended so as to remain on the rat in the cage. Again, however, it appeared to the experimenter that the rat's attempts to bite the electrodes and his frequent tangling in the wires restricted the frequency of the seizures. Since one of the main purposes was to produce as many seizures as possible, the electrodes were removed and the rat was subjected to the auditory stimulus without such 'distractions.' Twenty sec. after the start of the seizure the rat was taken out and was placed on the floor of the Pavlovian frame, electrodes were attached and recording was started—all within 5–10 sec. of the animal's removal from the seizure cage. This loss in time was actually of small consequence for the following reasons. Lowest heart rates occurred during the *convulsive* seizures; and in 50 percent of the instances of this type of seizure ($N = 41$) the low heart rate was not attained until 5–20 sec. after the commencement of recording (see Fig. 1). Four animals which gave early indications of chronic susceptibility to seizures were studied. Results from 50 successive days of auditory stimulation were analyzed (1) for lowest heart rate in any 10 second period[2] during comatose stage, (2) for type of seizure. Seizures were classified into

[1] Lindsley, Finger and Henry (1) also encountered this problem.

[2] 10 sec. was believed to indicate a period of heart action which would be more than part of a very temporary fluctuation of the heart rate.

two types, (a) the restricted attack where activity, while great, appears to be under the animal's control and stops with cessation of the auditory stimulus (this type cuts across Maier's type A and B), and (b) the convulsive attack where the animal seemingly loses all control over its actions which continue after cessation of the bell. It may involve convulsions with violent kicking of all four limbs, the animal lying on its side, or it may involve extension and rigidity of the limbs. (This type includes Maier's A + C and A + E types.) Both types of seizures are followed by a passive phase. Intermediate types of seizures which cut across the above categories occurred but were not recorded.

TABLE I

MEAN OF LOWEST HEART RATE OBSERVED DURING A 10 SECOND PERIOD IN THE COMATOSE STATE FOLLOWING A RESTRICTED OR CONVULSIVE ATTACK COMPARED WITH MEAN OF NORMAL HEART RATE IN 4 SUSCEPTIBLE ANIMALS

Animal	Mean Normal Heart Rate as Determined Over 15-Day Period (a)	Lowest Heart Rate in 10 Sec. of		Critical Ratio	
		Restricted Seizure (b)	Convulsive Seizure (c)	(a) : (b)	(b) : (c)
No. 13	497±21	389±30 (N=6)	263±69 (N=6)	8.2	4.2
No. 5	418±34	223±24 (N=8)	137±20 (N=9)	16.0	7.9
No. 9	475±20	282±13 (N=7)	134±26 (N=17)	27.2	18.3
No. 12	478±11	320±26 (N=12)	169±19 (N=9)	19.7	15.6

Comment.

(1) The lowest heart rates in the case of each animal followed the convulsive type of seizure.

(2) The lower rate following the convulsive seizure held for the individual animal, but not between animals. That is, the rate in a convulsive attack in one animal, while lower than its own rate in a restricted attack, might be higher than another animal's rate during a restricted attack (*e.g.*, rats number 5 and 13). The low rate during the comatose phase is therefore determined by the type of seizure and by the animal itself.

Discussion.—As an immediate aftermath of violent motor activity an increased heart rate might be expected. The converse, however, is the case. The low heart rate in the comatose state of audiogenic seizure, together with the other physiological disturbances observed, *i.e.*, cyanosis, loss of pupillary reflex, and ejaculation, suggest a predominance of the inhibitory system. It is of interest to conjecture whether any relationship exists between the atypical heart rate development in the rat (Marcuse and Moore (**4**) in which an inhibitory predominance is also suggested) and the low heart rate in the comatose state, and whether this may be a clue to the susceptibility of the rat as a species to these seizures following auditory stimulation.

Summary.—Heart rate occurring in the comatose state of the audiogenic seizure was found to depend on both the severity of the seizure and the individual animal. The average heart rate decreased from a normal level of 467 beats per minute to 224 in the comatose

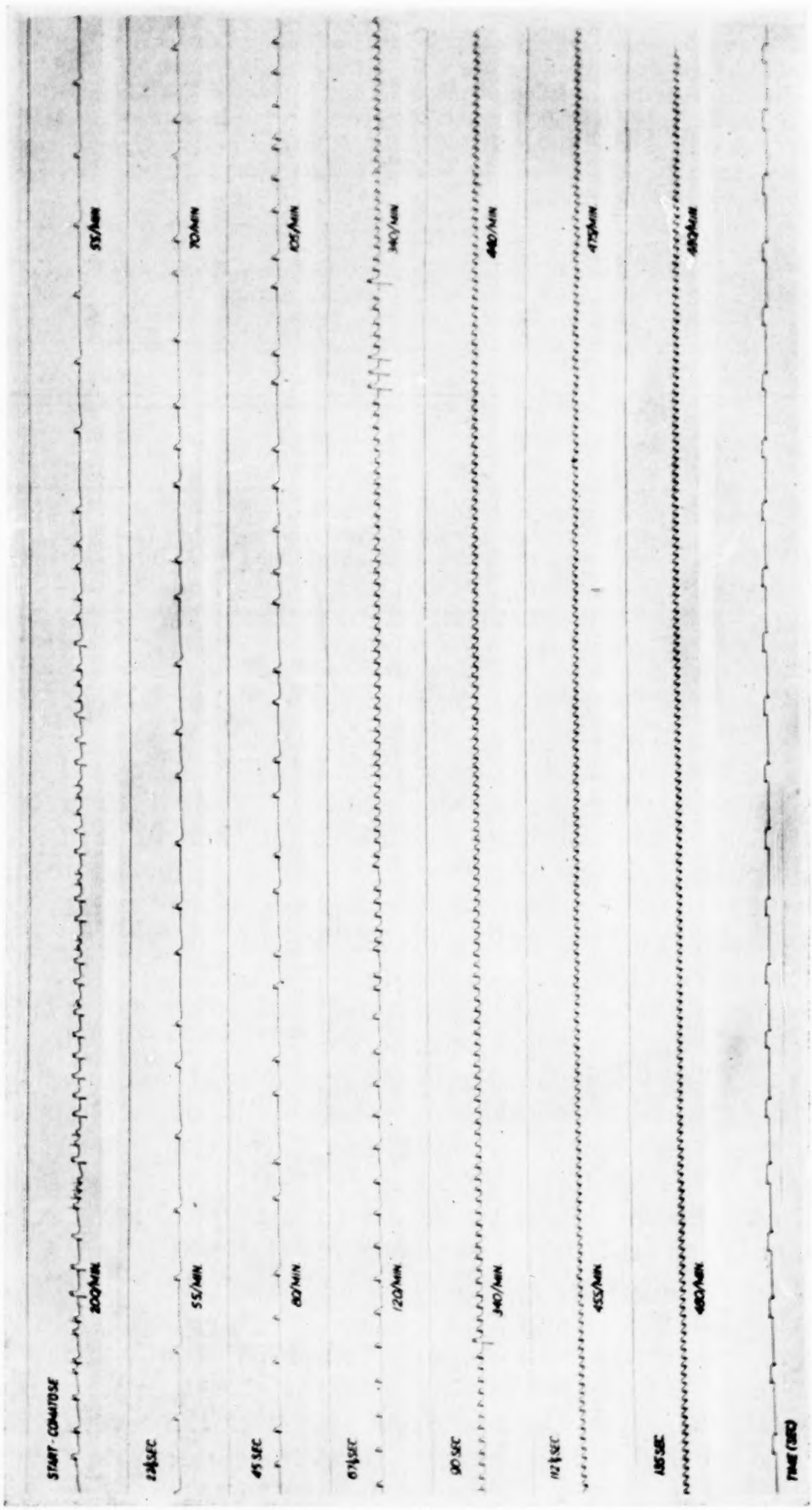

FIG. 1. Heart rate in comatose state of audiogenic seizure and subsequent recovery.

state, and in individual cases decreases in rate to 50 beats per minute were recorded.

(Manuscript received February 2, 1943)

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